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WORKSHOP PRACTICE

VOLUME II

VOLUME II

PATTERN-MAKING AND FOUNDRY WORK

BY

J. McLACHLAN AND CHAS. A. OTTO

WORKSHOP PRACTICE

A PRACTICAL WORK FOR THE DRAUGHTSMAN,
THE MECHANIC, THE PATTERN-MAKER, AND
THE FOUNDRYMAN

SECOND EDITION

EDITED BY
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PREFACE

THIS volume deals exclusively with the subject of pattern-making and foundry work and is intended for the benefit of all those whose calling brings them into touch with this highly specialized branch of engineering work. The authors have treated the subject throughout from the practical point of view, and the information given in the following pages will directly benefit the pattern-maker or the foundryman who wishes to expand his knowledge and improve his position. All aspects of the subject are adequately dealt with.

For convenience and to avoid confusion the matter has been divided into three sections, namely, *Pattern-making*, *Iron and Steel Founding*, and *Brass Founding.*

Whilst this volume will be found of the greatest utility by practical pattern-makers and moulders, it is also a useful work for study and reference by engineering draughtsmen, mechanics, and apprentices.

CONTENTS OF VOL. II

PAGE

PREFACE V

SECTION V

PATTERN-MAKING 3

Introductory—Materials—Allowances—Core-prints—Jointing—Forms of construction—Small patterns—Cylindrical patterns—Box-up construction—Barrels—Boxed-up work—Various types of patterns—Skeleton patterns—Sweeping boards—Composite patterns—Core-boxes—Pattern plates—Gearing—Pattern shop machines—The lathe—Saws—Sand-papering machines—Trimmers—Wood millers and other machines

SECTION VI

IRON AND STEEL FOUNDING 111

Introduction—Melting equipment and appliances—Metal mixing—Moulding materials—Green-sand moulding—Dry-sand moulding—Loam moulding—Cores and core-making—Runners and risers—Contraction difficulties—Assembling and closing moulds—Moulding and core-making machines—Core machines—Dressing castings

SECTION VII

PAGE

BRASS FOUNDING 205

Introduction—Melting equipment and appliances—The electric furnace—Gas-fired furnaces—Oil-burning furnaces—Coke furnaces—Reverberatory furnaces—Non-ferrous alloys—Brass and bronze moulding—Aluminium founding—Die casting—Melting aluminium alloys—Casting alloys—Heat-treatment of castings—Magnesium alloy founding—Melting magnesium alloys—Heat-treatment of magnesium alloy castings—Machine and plate moulding—Dressing castings

INDEX 269

SECTION V

PATTERN-MAKING

BY

J. McLACHLAN

AND

CHAS. A. OTTO

SECTION V.

PATTERN-MAKING

INTRODUCTORY

The Pattern-maker is primarily a woodworker, although patterns for repetition work are frequently made of iron, brass, and aluminium, and skill in the manipulation of woodworking tools is only one of several qualifications required by the pattern-maker.

While the fitter and the machine-man—and the moulder also for that matter—have a shaped construction on which to work, the construction of the pattern is the first concrete step in engine or machine manufacture, and the pattern-maker has to visualize from a drawing the design of the casting. From the tracing or blue print supplied by the drawing office a workshop drawing is made. The drawing supplied may be to any scale, but the pattern-maker's drawing must be full size, and special allowances must be made for contraction, machining, and other factors that affect the finished casting.

There are four distinct operations in the production of metal castings. A drawing first has to be made, and this may be done by a draughtsman, or in small repair shops the pattern-maker has to be his own designer, and must therefore have a rudimentary knowledge at least of the principles of machinery design. Secondly, a pattern with such core-boxes as may be necessary is made, by the aid of which a mould is prepared in the foundry, and the last operation consists of melting metal of the necessary chemical and physical characteristics and pouring it into the mould at the correct temperature.

The pattern-maker ought to have a good knowledge of foundry work, of the peculiarities of molten metal, and of finishing processes, because he must determine the amount of machining necessary.

There are, roughly, three grades of patterns. For repetition work patterns are usually made for machine or plate moulding, and high first cost is an ultimate economy, because of the saving in foundry costs, and the same may be said of standard designs of patterns that will be used frequently over many years. A wrongly-constructed pattern, or one that is made without regard to moulding, may make the production of a mould either impossible or extremely difficult, and certainly will necessitate many joints and much patching of the mould produced.

Patterns from which a number of castings will be required, after which they will not be needed any more, must be properly and strongly constructed, but durability is not essential, and there is no need to paint and varnish them as in the case of standard patterns.

The cheapest grades of patterns are those made for one or two castings. They may be loam patterns made by the moulder under the supervision of the pattern-maker, and by the aid of strickles and parts supplied by him, or they may be skeleton patterns requiring for their construction a minimum of timber and labour.

The pattern-maker does not require as many tools to-day as at one time, because all but the smallest pattern shops are well equipped with machinery. The most necessary tools are the trying, jack, and smoothing planes, the cross-cut and tenon saws, a round sole plane with a number of soles of varying radii, several paring chisels from $1\frac{1}{2}$ in. or $1\frac{1}{4}$ in. to $\frac{1}{16}$ in.; gouges, compasses, trammels, calipers and dividers, trying and set square, hammer, pincers, bradawls, oilstones, screwdrivers, a scriber, standard and contraction rules, and a set of wood-turning tools.

MATERIALS

Timber. Every pattern shop should stock two grades of timber, which should be stored separately. Standard patterns ought always to be made of the best quality of wood. Yellow pine is undoubtedly the best timber for pattern-making. It is straight-grained, is soft and easily worked, and it takes varnish. Some years ago cypress looked like becoming popular, but this timber warps very readily and, if carving has to be done, it is not satisfactory. One great advantage it has, however, is its width and freedom from knots. For small standard patterns mahogany, or rather baywood, surpasses all other kinds. Teak is sandy, and takes much more time to work than baywood. Beech, sycamore, and maple make good patterns, but they are very hard, although, if the major part of the work has to be done in the lathe, any one of these woods is better than baywood, and they turn easily.

Plywood is not used extensively for pattern-making, but for some classes of work it is useful. It is not a satisfactory material for the construction of patterns from which a large number of castings will be made or for those of a standard kind. The objections to it are that plywood is not sufficiently strong for heavy ramming, and moisture may affect the surface of the pattern. These objections are based on carelessly made plywood patterns, however, and for one-off jobs in repair shops plywood could be more used as it is often a time saver and also a cost reducer. It is particularly suitable for making templets. For highly finished patterns, on which it is necessary to use hand edge tools, plywood is not satisfactory. An advantage of plywood is that it does not shrink or warp, but to prevent disintegration the edges must be waxed. Plywood patterns are sometimes made for standard work and the surfaces have then to be well protected from damp by paint and varnish.

Seasoned timber is only relatively dry. Unless the surface of timber is protected by paint or varnish it is always subject to change, because it will absorb moisture from the atmosphere in damp weather and give it off in dry weather. Thus, even well-seasoned timber will warp unless precautions are taken to prevent it from doing so. The grain of timber is formed by the spring and autumn growths, which are indicated by annular rings. Almost invariably there is considerable difference in density between the spring and autumn growth, with the result that the texture of the wood varies, and it absorbs or gives off moisture unevenly, which is largely responsible for the wood warping. An important requirement of a pattern-making wood is that it should have an even texture, that is, little difference between the spring and autumn growths.

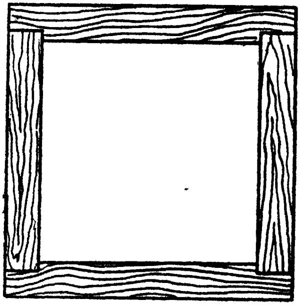


FIG. 1

The tendency of timber to warp is counteracted by correct jointing. It is good practice to build a pattern so that each piece of timber in its construction is prevented from warping by other pieces, and also that dimensions will not change through the timber shrinking or swelling. If a block 9 in. thick were required it would be better to build it of several thicknesses of timber, with carefully planed and glued joints, than to use one solid piece 9 in. thick. The best construction, were the shape to remain square, would be as shown in Fig. 1, but if the block has to be carved the jointing would be as shown in Fig. 2, which is sometimes called "back to back" jointing. The adjacent thicknesses of timber are jointed with the annular rings of one opposed to the annular rings of the other. The wrong way to joint timber is shown in Fig. 3; the tendency of a block to warp built in this way is not much, if any, less than if it were made of one piece of timber.

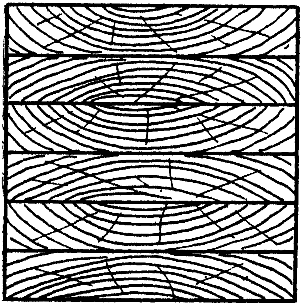


FIG. 2

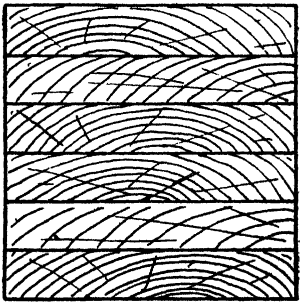


FIG. 3

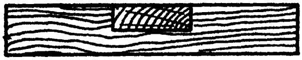


FIG. 4

If, instead of a block 9 in. thick being required, a pattern had to be made from a piece of timber 1½ in. or 2 in. thick, if large, the timber would be framed, but if comparatively small one piece of timber would be used, and the tendency to warp might be counteracted by inserting a batten as shown in Fig. 4.

It ought always to be remembered that "shakes" in timber or splitting result from the same primary cause as warping, that is, from the shrinking of the timber due to it drying ; in other words, it is caused through the separation of the cellular tissue due to shrinkage when drying, and the direction in which timber changes its form due to the giving off or absorbing of moisture is in the direction of the annular rings and at right angles to the medullary rays.

When metal patterns are required, wood or plaster patterns have first to be made, unless the moulds for the metal patterns are swept out by means of strickles and pattern sections supplied by the pattern-maker. The wood pattern must be made with additional contraction and machining allowances. Metal patterns are invariably machined or filed all over, and loose parts are carefully fitted and kept in position by dowels.

For all classes of pattern-making glue is useful, but glued joints should never be exposed without a protective coating of paint or varnish. For one-off patterns that are not painted, glue should not be used unless the joints are subsequently smeared with varnish. Glue is useless unless the joint surfaces are planed quite straight ; if they are scratched, thinly coated with glue, and rubbed together to fill the pores and to expel superfluous glue a permanent joint will result. Timber must be dry if it is intended to be glued, and any subsequent absorption of moisture will affect the glued joint and render it less permanent.

Metal. The development of plate moulding, and particularly machine moulding, caused attention to be given to metal for pattern-making purposes. Apart, however, from repetition moulding, metal is frequently used. A number of castings may be required that, while not justifying repetition methods, could be made only from a solid pattern with core-boxes or a very costly shell pattern and, if the casting is thin, it might be rammed out of accuracy by the moulder. It may then be worth while to make a comparatively flimsy pattern without regard to durability, from which one casting can be made and this casting, either machined or not, may be used as a pattern. The cover shown at Fig. 5 is an example of this kind. The contraction difficulty may be overcome on a job up to 24 in. or so in diameter or in length by additional machining allowances, and if the iron—it is usually iron—pattern is moulded and dressed with reasonable care it is quite satisfactory. An advantage is that it can be stored and used occasionally over years, although it is necessary to take precautions against the pattern rusting.

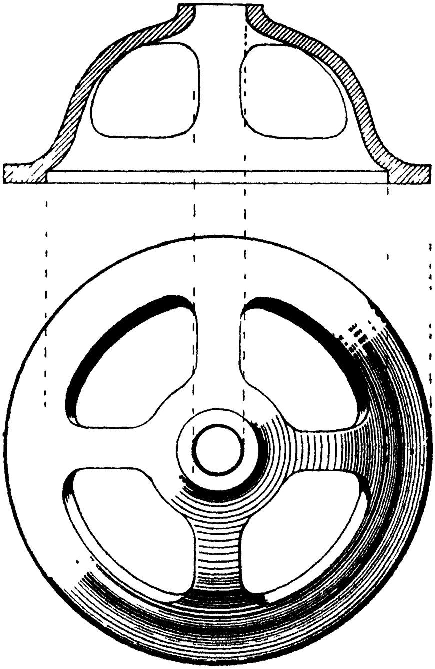


FIG 5

If an iron pattern is properly prepared it is long lasting, but for the most satisfactory results each part should be machined if possible, and any parts that cannot be machined ought to be filed and scraped. It is necessary to take precautions against rusting, and a successful method is to coat patterns with beeswax. To apply the wax successfully, the patterns must have a coating with a solution of sal-ammoniac and water, allowing them to stand until the whole surface is thoroughly rusted. A vigorous rubbing with a wire brush will remove the rust, and a good polish can be given to the metal with a piece of coke. This provides an ideal surface for the wax, which should be applied warm with a soft brush, the pattern having been previously heated. The surface can be polished when it has cooled. While this surface will remain rust-proof for a considerable time, the wax is gradually worn off during operations in the foundry, hence it is advisable to give another coat of wax occasionally. When non-ferrous metal patterns are used, it is not necessary for them to have any protective coat.

In repair shops an old casting is frequently used as a pattern. The usual procedure, if a complicated casting which has become defective is to be replaced, is for the pattern-maker to take measurements from the casting, and it is not always an easy matter to obtain sizes of intricate cores. These measurements are taken with the standard rule and a workshop drawing made with the contraction rule. If the coring is intricate, the casting may be used as a pattern and core-boxes made, or the core strickled, the pattern-maker having in mind that an hour saved in the pattern shop does not result in speedy production of the casting if the moulder is caused more work. It may be necessary for the pattern-maker to work in close conjunction with the moulder to ensure that correct metal thicknesses are obtained. Undercut parts may have to be made with drawbacks, or by using cores, the speed of production being almost as important as accuracy.

Metal patterns are chiefly used for repetition work, and several factors such as size and convenience decide as to whether iron, brass, or aluminium is used. The great value of metal patterns over wood patterns, even if these are made of hardwood, is that they do not shrink or warp, thereby ensuring extreme accuracy not only for large quantities cast at one time, but over a period of years, and they deliver easily from the sand; perhaps their chief disadvantage is that they cannot readily be altered, but in small repetition work this is not vitally important. The initial expense is always greater because a wood pattern must first be made. Plaster of Paris may be utilized in conjunction with wood.

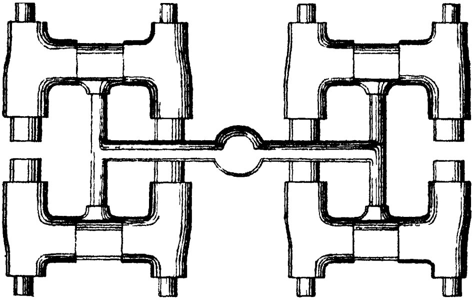


Fig 6

In some shops wood patterns are mounted on plates for machine moulding when the number required is not too large, but for standard work of which large quantities of castings are required, metal castings are made. Fig. 6 shows a typical plate with the necessary gates. With regard to the design of the runners this is frequently a matter that is the subject of arrangements between the pattern shop and the foundry. From the metallurgical point of view rectangular runners are sometimes preferred as aiding the trapping of slag by keeping it in the runners instead of permitting it to flow freely into the casting, but much depends upon the relative positions on the plate of the casting, the runners, and the feeder. A disadvantage of the rectangular runner is that it causes the sand to wash away very easily, but it has the advantage of a greater surface area and consequently quicker cooling facilities. The size of feeders is usually determined by experience with particular types of castings.

Weight is often a determining factor as to whether patterns will be made of metal or wood, aluminium being excepted. It has been quite truly said that a good lift is an essential factor in the production of a good mould, and, therefore, the weight of the pattern must be considered, because, if a pattern is easy to lift, it is easily handled and can be more accurately withdrawn from the mould. There is always a greater tendency for dimensional inaccuracy when two moulders withdraw a pattern than when one moulder withdraws it alone. It is, therefore, essential for the pattern to be as light as possible, taking into consideration the strength necessary to withstand the service requirements of the foundry. With very small castings the weight factor is not so important. Metal patterns are often unnecessarily heavy and strength could be obtained with thinner sections of metal reinforced by ribs, but this applies more particularly to hand moulding. Cast iron is still extensively used as a pattern-making material, and it is suitable, although its relatively great weight causes fatigue of the moulder which influences production and may have an effect on the quality of the casting. It has been proved that cast-iron patterns are most durable for use on the sand-slinger machine because the surface does not become pitted by the minute slag inclusions in the sand. For a similar reason it is a useful metal for core-boxes to be used on a core blowing machine.

Brass of varying composition is much used for small pattern work and particularly for spray patterns. It retains its finish better than cast iron, has almost indefinite use, and brass patterns actually improve their finish with use. They are more ductile than cast iron and can be roughly handled. Sometimes a combination of wood and metal is used in pattern construction, the main body being made of wood and bosses; ribs, etc., of metal. Brass is frequently preferred in this class of work and one main advantage of such a combination of wood and metal is that alterations in design can be more easily effected without a completely new pattern having to be made and, in the case of plate patterns, without the pattern having to be removed and repositioned on the plate.

Aluminium has become increasingly used for pattern-making in recent years, but it is scarcely satisfactory where service conditions are likely to be severe. If the moulder does not exercise reasonable care the surface of an aluminium pattern may soon become pitted by careless use of the vent wire. The following alloy has been recommended: Zinc, 12½ to 14½ per cent; copper, 2½ to 3 per cent; iron and silicon, 1·5 per cent maximum, and aluminium the remainder.

Steel is rarely used for pattern-making, but, at the other end of the scale in the factor of strength, white metal is occasionally used by foundries that have to make duplicates of customers' patterns, an important point in its favour being that special compositions have no appreciable shrinkage. For the filling of screw head slots in small wood patterns beeswax may be used, and shellac is even better because it is harder. This is quite an important matter affecting production. In cast-iron patterns, wax is a suitable material; in aluminium patterns a solder may be used; and for brass patterns also solder may be used. The filling of screw head slots is part of the metal pattern-maker's job. The invariable procedure, when a metal pattern is required, is to make a wood pattern to the required design without having regard to moulding problems. Having completed this wood pattern, moulding is then considered before the metal pattern is made. The so-called metal pattern-maker is sometimes a workman who has no real knowledge of casting production, but the majority are now familiar with the principles involved.

Plaster of Paris. Plaster of Paris, or "stucco," is sometimes used for the repair of old patterns, and for the working-up of fillets, especially large fillets. It may also be used for making bend patterns. For heavy-engine or machine tool work, where it could be used, it is usually quicker and, on the whole, cheaper to make a skeleton pattern.

The fundamental difference between the light casting trade and ordinary engineering is that for grates, rain-water pipes, gutters, etc., the eye, within limits, is of greater importance than dimensions. In the construction of a pattern for any part of moving mechanism accuracy is of more importance than appearance. When making plaster patterns, strickles and boards are largely used, and, for irregular shapes, the hands. It is possible to pare the plaster, using a templet as a guide, but there are limits to this.

In the engineer's pattern shop the pattern of irregular shape is the rule rather than the exception, and it is frequently difficult to visualize the finished pattern and core-boxes after examining the blueprint or tracing. In almost all pattern shops there are jobs, circular and otherwise, which could be run up in plaster much cheaper than they could be built and turned in wood, and give equally good results in the foundry.

In engineering pattern shops many jobs have to be done which approximate closely to what are called light castings and, in all repair shops, plaster could be used more than it is. It is quite common, for instance, for the patch to be fitted over a crack or other flaw on, say, a condenser or cylinder. The making of a pattern is rather a tedious job. The patch is made sufficiently large to enable it to be fastened by means of studs or screws on the casting at a reasonable distance from the crack; it may be cast in gunmetal or ordinary brass, and should be about ½ in. thick.

In designing the patch a good deal is usually left to the pattern-maker. The *modus operandi* is usually as follows: A block of wood free from knots is bedded on the casting, chalk or red-lead being freely used, after which the required thickness is gauged round the edge. As the patch may be fitting into a large fillet or round a corner, calipers are used to test the thickness. To prevent it from warping the patch is usually painted and varnished before going into the foundry.

Varnish. Shellac varnish is made by dissolving gum shellac (orange shellac) in methylated spirits. A jar is filled with shellac and methylated spirits added to cover it. To restore yellow shellac varnish that has become "dirty" a little powdered oxalic acid should be added to it. It is sometimes advisable to colour varnish, and lampblack may be added for this purpose, or vermilion. Patterns should be varnished thus: all surfaces should be smoothed with glasspaper and all holes filled with beeswax, shellac, or putty. Two, or at most three, coats of varnish are sufficient, and the surfaces should be smoothed with fine sandpaper between the coats.

Sandpaper is a useful material for a pattern-maker, but planed surfaces should never be sandpapered.

Sandpaper is not for shaping work, but for smoothing surfaces that have already been made as smooth as it is possible to make them with edge tools. Rubbing blocks—convex, concave, and straight—should be used whenever possible. Rubbers may be of cork or of wood with facing of cork or other slightly resilient material, the sandpaper being wrapped round them.

Screws are more used for pattern-making than nails, because there are so many parts that have to be loosened in the foundry, and also because they ensure greater strength and accuracy than nails. When nails are used they should have smaller heads, and cheese-headed screws are preferable for attaching pattern sections that must be loosened when moulding.

In order to give greater strength and improve their appearance castings should have corners rounded. While the abruptness of a change in the direction of the metal thickness is slightly modified with fillets, they should be made proportionately, otherwise the casting will tend to draw. To reduce labour, leather fillets are largely used instead, although separate wood fillets may be used for straight parts. These leather fillets are fastened with glue, dumb-bell rubbers being useful to press them into position.

PATTERN ALLOWANCES

The pattern-maker is frequently responsible for modifications of a design in order to facilitate the production of a casting in the foundry and to increase the prospects of a sound casting. In addition to any slight alterations, such as the introduction of fillets, rounding corners, or making abrupt changes of metal thicknesses more gradual, introducing webs or ribs or varying their positions, cutting through a wall of metal, or increasing the size of hole through some unimportant part of the casting, the pattern-maker is also responsible for external contraction allowances. Moulds must be made larger so that the metal cast in them will conform to requirements when cooled down.

Different mixtures of the same metal vary in the amount of their contraction, owing to the influence of their components. White iron contracts more than grey iron, light castings more than heavy castings, thus for guttering pipes and any light work which has little or no obstruction to contracting, an allowance of $\frac{1}{8}$ in. to the foot is general practice. Work of a complicated nature also contracts less, depending upon the counteracting influences. An allowance of $\frac{1}{16}$ in. to the foot is very frequently used for such work, and there are instances when no allowance at all is made. These latter cases are rare, and refer to such cases as breeches pipes when the centres between two branches, according to their design, are set out with the standard rule, or in semicircular castings open at the ends and carrying an additional structure on the crown which causes the diameter to open rather than contract.

Even in the making of one casting the allowances often vary for different parts. A large reciprocating cylinder is an instance of this; $\frac{1}{16}$ in. to the foot is usually allowed on all dimensions excepting the height, and with this practice varies considerably. Some make no allowance for contraction but take the precaution to have additional machining allowance, while others that allow for contraction are careful to back up the flanges, in order that if the casting should not contract the amount for which allowance has been made, the flanges will at least be thick enough after they are machined.

It is not suggested that castings do not contract to the same extent vertically as horizontally, and the method of moulding is a probable cause, for it is well known that moulds have a tendency to " creep " when there are many joints. It is the practice of some pattern-makers, because of this, when constructing small and medium sized work to make distances from the main horizontal joint less than indicated in the drawing; thus, for grey iron work the measurements would be made with a standard rule, and for brass work with an iron contraction rule.

The general allowance for cast steel is $\frac{1}{5}$ in. to a foot, and for work up to about 2 ft. this is quite satisfactory, but above that it is profitable to get in touch with the foundry doing the work, for their contraction allowance may be anything from $\frac{5}{32}$ in. up to $\frac{1}{4}$ in. to the foot, according to the work to be cast and the composition of the steel. The pouring temperature of the metal influences the amount of contraction.

There is another allowance to be considered with steel castings which, though not concerned with contraction, should be made when the castings are to be annealed. The pattern is usually prepared to give at least $\frac{1}{16}$ in. increase in the thickness of metal to allow for the removal of scale which is formed on the surface after the casting has been annealed.

The usual contraction allowance for brass and gunmetal is $\frac{3}{16}$ in. to the foot, but $\frac{5}{32}$ in. to the foot is in common use for large work, slight variations being made according to the shape of the casting. These are determined as the result of experience with similar types of castings. For aluminium, an allowance of $\frac{1}{4}$ in. to the foot is in frequent use, although many use the contraction rule for cast steel or brass for comparatively small work, but in complicated work an allowance of $\frac{7}{32}$ in. to the foot is sometimes used.

Camber. In every section of engineering the question of camber frequently arises. Few castings cool uniformly because, even though they may be of similar sectional thickness, the mould influences the rate of cooling and they cool irregularly, and castings are likely to warp or camber. In many instances the moulder can counteract the tendency, but in other instances it is necessary for the pattern-maker to make an allowance. The exact amount of camber, which is the term given to the allowance that is required, is usually arrived at by the process of trial and error, and this may be satisfactory when a large quantity of castings is required, but when only one or two castings are required "wasters" result unless the most careful calculation, combined with good judgment, is made. The tendency to warp is greater when castings are long compared with their depth or breadth. Castings such as lathe beds, planer beds, "T"-slotted plates, the tips of propeller blades, etc., are types subject to this change of form, also gutters and other parts in the light castings trade.

It is sometimes mistakenly thought that only long castings will warp. The truth is, of course, that in short castings the amount may be negligible—$\frac{1}{16}$ in. perhaps—whereas in a casting of the same section that is 6 ft. long the amount may reach $\frac{3}{8}$ in. or so. Engine beds of the girder type will sometimes warp, and even if the pattern-maker makes an allowance, he takes the double precaution of leaving additional machining on faces to compensate for warping. It is not always possible to allow a uniform amount of camber on a pattern, as much depends upon the design.

Allowances for machining may be said to depend upon the metal to be cast, the size and design of the casting, the manner in which it is to be cast, and sometimes on the type of machines to be used. Cast iron chills in contact with the mould, and more allowance is generally necessary than for non-ferrous alloys. Large castings require more allowance to cover variations in contraction and yet ensure accuracy in finishing.

The upper parts of a casting, particularly in large work, need more metal for machining than the lower parts because of dirt or " kish " rising with the metal. In modern moulding practice, particularly in repetition work, the allowance is cut to a minimum, thus in small brass work it may be only $\frac{1}{32}$ in. but for other work $\frac{3}{8}$ in. may be necessary and even more for large steel castings.

Another allowance is taper. On the vertical sides of deep patterns it is necessary to leave taper which may be $\frac{1}{16}$ in. for each foot of depth. Taper facilitates drawing the pattern and prevents damage to the mould and, incidentally, the pattern also.

CORE-PRINTS

In a very large proportion of designs it is not possible to make patterns that are exact replicas of the castings required. The solid patterns in many cases require core-boxes, which are the shape of the inside of the castings. When the mould and the cores have been made in the foundry it is necessary that the cores should be properly supported in their correct position, and this is done by means of prints which are attached to patterns and really form shells on which the ends of the cores rest. With occasional exceptions, cores are always left by the pattern when it is convenient to do so, because core-boxes, especially for intricate castings, are costly. It is not right to assume, as is sometimes done, that cores are entirely the moulder's concern and prints the pattern-maker's. The pattern-maker will frequently modify methods of making core-boxes and prints to suit the moulder. The essential thing is that when the cores are made and placed in position in the mould they should be supported so that they will not change their position when metal is poured in. Owing to bad printing a core will sometimes float so that, instead of the metal being of equal thickness below and above the core, there will be a double thickness of metal below and none above.

Core-prints, whenever possible, are of the same shape as the core, and are invariably coloured differently from the rest of the pattern in order that the moulder may recognize them as prints. The pattern-work for many delicate castings has all to be made in a core-box, one such example being the pump impeller shown in Figs. 7 and 8. Both views are sections: Fig. 7 being on the line *AB*, Fig. 8 on the line *AB*. To make this pattern several courses of segments are built on either side of a centre plate and on these segments the top and bottom flanges, also in the form of segments, are screwed. It will be observed that the prints have not

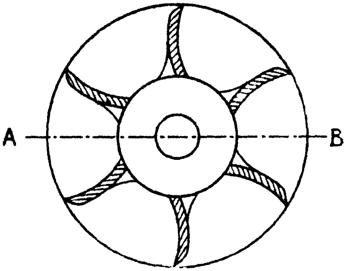


FIG. 7

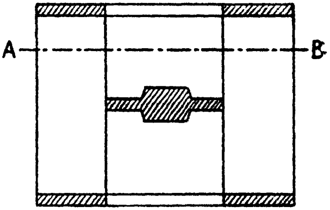


FIG. 8

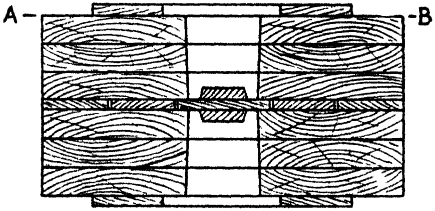


FIG. 9

been carried to the centre, but the inside diameter of both prints is well tapered. If the core was carried to the centre the moulder's work would be made easier, as he would be able to part the mould on the line *A B*, Fig. 9, but it is not as satisfactory as mitreing cores to the centre.

On the machine faces of large jobs it is customary, instead of machining the whole surface, to recess certain portions, and it may be convenient to form this recess in the mould by means of a core, a print for which must be fastened to the pattern. Such a print may be ¾ in. or 1 in. thick. Prints of this kind, if the sides of the print are vertical in the mould, must be tapered, just as round prints, which are the most common form of prints, should be tapered. The taper is not merely to facilitate withdrawal of the print from the mould, but also to minimize the danger of the core being crushed while it is being set in position.

With regard to circular prints a large diameter print does not usually require to be as thick as one of small diameter. When possible, the small diameter prints should be turned with a dowel, as they can be more accurately located on the pattern, and their position is not easily altered in the foundry ; especially is this useful if many prints are required, because they can then be turned in one length in the lathe. An advantage of such prints is that they always remain circular, such shrinkage as may occur being uniform around the diameter.

It is sometimes convenient to core off external parts of castings: an instance of this is illustrated at Fig. 10, which shows a bracket on the top of a cylindrical pattern. The ribs and flanges are built on a block which is well tapered as it forms a print, a core-box being made to suit it. The same practice is sometimes adopted with top branches, instead of turning a long print on the branch over which the flange would fit, or dowelling the flange and the print on a separate branch piece. An advantage of the method is that there is less likelihood of errors occurring in the foundry because, in loosening a foot or a branch from the pattern, during the time of ramming, they may be rammed out of their correct positions. Fig. 11 shows a branch made with a circular core print on the same principle as the bracket on the cylindrical pattern. The method of coring-off branches and brackets is sometimes adopted so that an alteration may easily be effected to the design. Other methods of dealing with top branches will be described later.

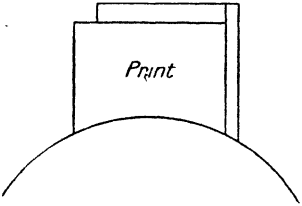


FIG. 10

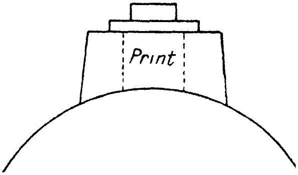


FIG. 11

A print may be a bearance or it may be merely a guide, and the thickness of prints depends upon several factors, such as the weight of the core to be supported and whether the whole weight will be suspended from comparatively small prints, or will have a large balancing bearance. Sometimes balance prints are adopted when only one print can be used to support the core, that part of the core which rests in the bearance print being heavier than the part which is inside the mould. On the other hand, a moulder can often fasten a core in its correct position even when a bearance print is not used, so that it will not move when the metal is poured into the moulds.

Sometimes prints are advisable, but are not really necessary. Fig. 12 shows a design of a square casting with a large hole in the bottom plate and smaller holes in the sides. The prints on the sides are not necessary, because the bottom print supplies a good bearance. The objection to not printing the sides is that a film of metal might be formed at the outer face. and if the moulder is not careful the core might be crushed while being placed. To obviate this, prints might be used, and in all probability they would be made, for convenience both in making core-box and core, separately from the main core, and set in position first. If they were not set before the main core it would be necessary to make a print reaching to the top face of the mould and a special core-box to extend the shape of the core. This form of print is called a tail-drop or draw-print. When possible, prints should leave the correct impression of the core, as the moulder can then more quickly see the shape of the various cores.

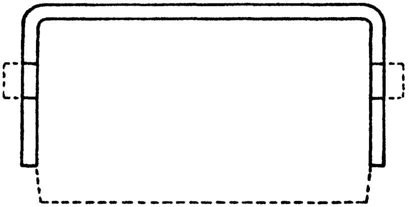


FIG. 12

Fig. 13 shows forms of tail-prints for a circular core. The advantage of the form *B* is that whether it is simply stopped over by the moulder, or a special separate core is made for it, the impression is more easily filled. The form *A* is quite suitable when the tail print is made as part of the whole core. For a one-off job it may be quite satisfactory to leave this stopping over to the moulder, but for repetition work a core-box should be made.

Accuracy in securing prints to patterns is very important; they should be carefully checked for correct position because, however accurate the cores may be, their correct positions in moulds can frequently only be determined by the impressions of the prints.

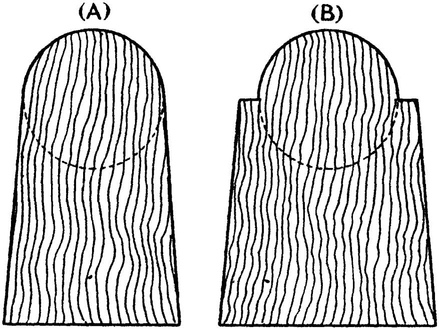


FIG. 13

JOINTING PATTERNS OR DIVIDING INTO SECTIONS

While accuracy of dimensions and strength coupled with permanence of form are very necessary in the construction of patterns, easy delivery from their moulds is not less important. In order to facilitate the delivery of patterns from their moulds, the majority require to be jointed, and jointing in pattern-making means the division of a pattern into convenient sections so that each part can be withdrawn from its mould separately. In many instances the division of the pattern is essential, otherwise the making of a suitable mould would be impossible, but jointing may be adopted to facilitate the preparation and subsequent cleaning of a mould, to give greater convenience in coring a job, or to reduce the number of joints in the mould. When setting down the work for which a pattern is required, attention should be concentrated on the moulding methods that will be adopted, so that the jointing of the pattern can first be decided, then the suitable construction of the various parts is more easily determined. Generally, whenever it is practicable to do so, the pattern joints should guide the moulder.

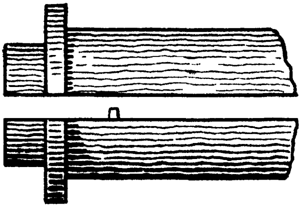


FIG. 14

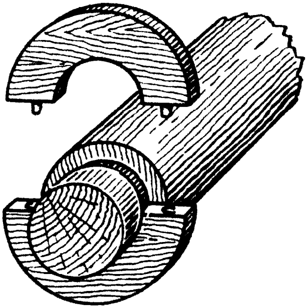


FIG. 15

Cylindrical work, if its length is greater than its diameter, ought invariably to be jointed along the centre of the diameter as shown at Fig. 14, while at Fig. 15 is shown an alternative method. Sometimes a pipe pattern will be turned from a solid piece of timber for quickness of production. The moulder has then to form his own joint, which must follow the line of the pattern joint shown at Fig. 14. It will be seen that at Fig. 15 the flange is made in halves and fits into a turned recess in that part of the pattern which forms the joint. The top half of the flange maintains its position accurately because of the recess and the dowels shown. By making the flange in halves a guide is given to the moulder when forming his joint and, what is more important, the top flange is left in the cope of the mould when it is lifted from the drag, and can be drawn out afterwards without any risk of damage to the mould.

The pattern shown at Fig. 16 is a double bend, and the joint must follow the centre line of the pipe. This, apparently, is a costly pattern, but if the timber is almost squared and the band saw is in good order, it can be cut neatly to the joint line and very little fitting will be necessary, in finishing, to form the joint. If such a pipe was of very small diameter it might be advisable not to make the pattern in two halves for strength reasons, but the moulder's work is increased considerably if he has to form his own joint for such a pipe.

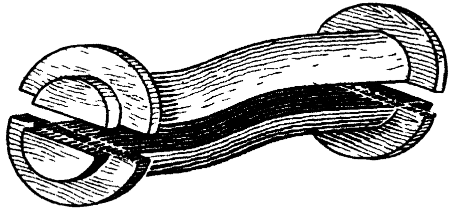


Fig. 16

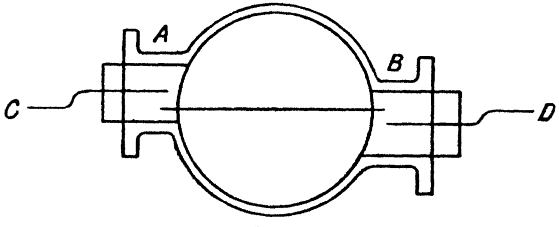


Fig. 17

At Fig. 17 is a cylindrical pattern with two branches, *A* and *B*, neither of which is on the centre line of the main body. The moulder's joint is indicated by the line *CD* ; it will be necessary for him to " step " his joint. From both pattern-maker's and moulder's points of view it is advisable to make the branches in halves. By doing so the pattern-maker can fit one half of each branch to the body and prove their position with set-square and rule from the centre line of the pattern. When the bottom halves have been fitted it is very easy to fit the top halves, which should be dowelled to the bottom halves and not fastened to the main body in any way, but the overlap of each half-branch should be made clear. In the case of the core-box for such a pattern the customary method would be to make the branch cores separate from the main core in order to reduce pattern-making costs, but a full core gives less trouble in the foundry.

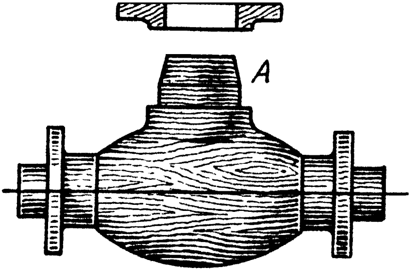


FIG. 18

A very common pattern in many pattern shops is the globe valve in one form or another. The valve seat is supported by ribs of metal to the metal of the valve chest. Depending on the design of the ribs, the cover flange may be on the pattern joint or parallel with it, as at Fig. 18. The determining factor is the setting of the cores, which can be effected more easily according to whether the print *A* is on the joint or parallel with it. If the valve is a small one the flange would be made to slip over the print, which would form a dowel. The moulder would then make a three-part mould having two joints in planes parallel to each other, but he may make a two-part mould by means of a loam cake.

There are several methods of dealing with branches that are not on the moulding joint. One is to make the flange in sections with a key-piece; this method is shown at Fig. 19, the key-piece being *A*. When the pattern is drawn from the mould the key-piece is drawn into the space left by the branch, and the other sections are then released. The various sections may be wired on as shown at *B*, or they may be screwed, the moulder taking out wires or screws as he is ramming his mould. The best way of fastening the section for convenience in moulding, and also in reassembling the pattern afterwards, is to dovetail each face with hardwood dovetails similar to those shown at Fig. 21. The key-piece should be marked on the inside for the moulder's guidance.

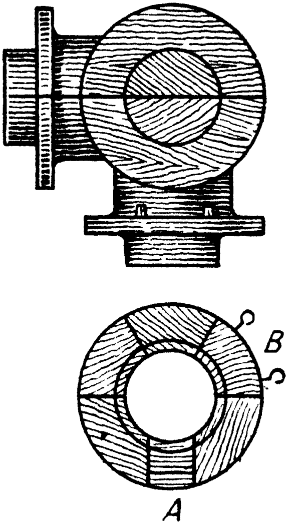


FIG. 19

Fig. 20 illustrates a representative type of valve or cylinder cover pattern. The convenient way to mould this would be with the face down in the mould. The top flange *B* might be made in sections or in one piece dowelled to the centre boss, and the stuffing box should be jointed for convenience in stripping. It will be noticed that there is no top print, the reason for this being that top prints increase the risk of a "crush" when the cope is being lowered.

Quite a different type of pattern from those we have been considering is that shown at Fig. 21. On the two ribs *B* and *C* are facings. The face *D* would be at the top of the mould, and the facings on the ribs might be wired or screwed only, but the best method would be to employ dovetails as shown.

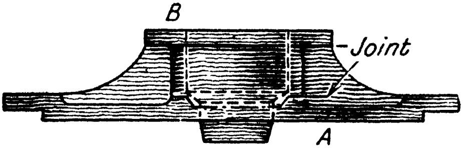


FIG. 20

Fig. 22 illustrates a pulley the pattern of which could be jointed in the line *A B*, or it might be made so that the face would be moulded down. Difficulties are caused by the design of the rim. If the face were moulded down it would be necessary to build the pattern with a circular print, when the rim would be formed in a core, a suitable core-box being provided. The method described would be satisfactory for a pattern of large or medium size, but for a small pattern the joint would be on the line *A B*, when it would be necessary to core out between the rim and the centre boss. An alternative method would be to joint through the centre plate and attach the outer facing in sections.

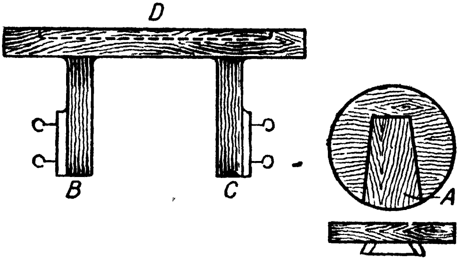


FIG. 21

The combined pinion and mitre wheel, Fig. 23, presents a number of jointing difficulties. The fact that the teeth are wholly and partially shrouded increases the difficulties. The mould requires to be in three parts, and the pattern jointed to enable the shroud *C* to be drawn separately. The pinion *B* should be loose, and the half shroud *A* should be divided into sections. The slip core indicated facilitates the work in the foundry, and a slight modification in design enabling shroud *A* to remain solid with the pattern would have little or no effect on the transmission, and would assist the moulder.

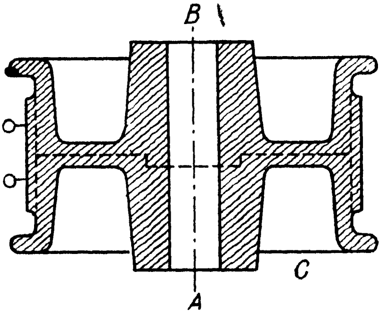


FIG. 22

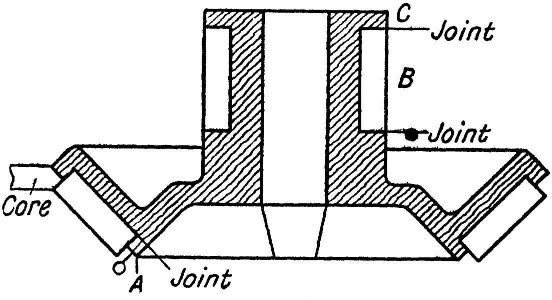


FIG. 23

The jointing of patterns is governed by a few simple principles that involve a knowledge of moulding, and the examples given translate into practice all or most of these principles. In large patterns involving much jointing the principles are the same as for small work.

FORMS OF CONSTRUCTION

There are standardized methods of pattern construction, but their application to different classes of work varies in pattern shops.

SMALL PATTERNS

In constructing medium-sized and small patterns there is very often a choice of methods possible. For instance, a circular pattern may be made as a staved barrel, or if it is short in proportion to diameter it may be built of laminae of segments. A staved barrel has the advantage that if the grounds to which the staves are fastened are properly made of well-seasoned timber it will last a very long time, and if for vertical moulding will deliver freely from the sand. The objection can be advanced against the segmental method that the periphery does in time become somewhat irregular, and thus making-up of the mould becomes necessary.

CYLINDRICAL SHELL PATTERNS

For cylindrical shell patterns, the segmental method is the only one possible. In building short cylindrical patterns, or parts which have to be fitted to a main body, there can be no doubt about which is the better method. Segments, if a band saw is available, can be very quickly cut and built and, if the segments are kept reasonably short, there should not be much trouble owing to unequal shrinkage. It is, therefore, quite good to build all cylindrical branches by the method, and, as a general rule, admitting of exceptions, to stave work that is of less diameter than length. Fig. 24 is a view of a pattern that ought to be built of grounds and staves, while Figs. 25 and 26 illustrate the segmental method, Fig. 25 showing uniform joints, while Fig. 26 shows staggered joints.

Jobs that are built of layers of segments should either be screwed, nailed, or pegged. Screws certainly make the best job, but they are more expensive than driving nails, and building is much slower. Where only two courses of segments are required, however, screws should always be used.

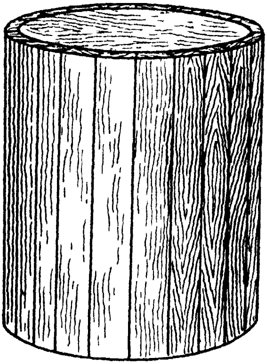


FIG. 24

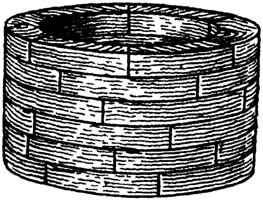


FIG. 25

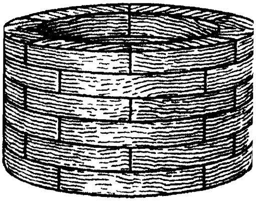


FIG. 26

Wire nails, either round or oval, are usually used in the pattern shop—cut nails seldom. They ought to be inclined at an angle to each other, so as to act like a dovetail and counteract any tendency for the segment to lift.

When it is impossible, because of the frailty of the job or because of the danger of " finding " nails in the lathe, to nail a job, pegs are used. Flat valve and pump covers are instances of jobs of this kind. The quickest way to peg a job is to saw a number of small square pieces ¼ in. thick and drive nails down through these. These small pieces can be afterwards split with a chisel and the nails drawn. When this is done, ¼ in. holes can be bored with a shell bit at the desired angle and the pegs dipped in the glue pot and driven in. The pegs ought to be made just under ¼ in. square. If the segments are well jointed when the nails are drawn, the segment will not rise.

It is a moot point whether work symmetrically built —the joint of each second layer of segments being directly in line—or work with " staggered " joints, is better. The former method looks better, and the latter method causes weakness if carelessly done. The former method is probably the better of the two.

The thickness of segments necessarily depends on the job under construction, but thinner segments make a stronger job, and in the case of a narrow ring the segments should always be thin.

Six segments in the circumference is the most useful number, but in small work four is better, just as in very large work it may be necessary to divide the circle into eight or even ten or twelve. The objection to four segments is that there is too much cross grain, which, when turning corners, flies off, making an unsatisfactory pattern.

BOX-UP CONSTRUCTION

Figs 27 and 28 show a plan of a small square boxed-up pattern constructed in the best possible way. It will be observed that what may be termed the ends are checked into the sides, and a check or rebate is also cut, so that a shelf is formed on which the top sits. Such a box may be either nailed or screwed together. Screws are preferable, and the screw holes may be plugged with side-grain timber. No hard and fast rule can be set down as to the size limit for this form of construction, but when 12 in. or 15 in. square is passed it is well to use frames, adopting open joints for the lagging.

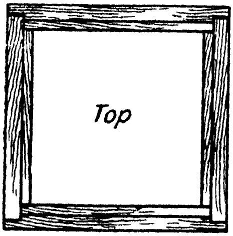


FIG. 27

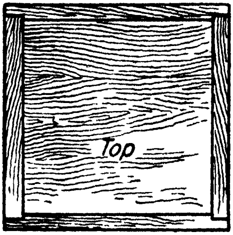


FIG. 28

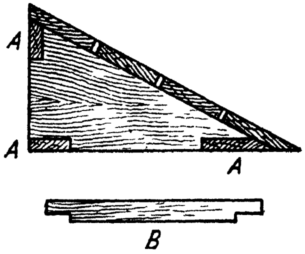


FIG. 29

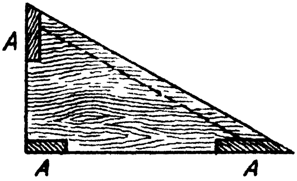


FIG. 30

Figs. 29 and 30 represent two forms of construction for boxing-up a triangular piece. It will be observed that, in both cases, the distance-pieces *A*, *A*, *A* are checked into the grounds which define the shape, those pieces being in turn rebated as at *B*, Fig. 29, to prevent the possibility of their being knocked in. Two views of a square box similar to that at Figs. 27 and 28, but larger, are shown at Figs. 31 and 32, which are plans. Before the skeleton is covered with boards, the top and bottom frames and the stays really constitute a square frame. The method of drawing the pattern from the mould sometimes determines the method of construction as, if it is intended to use a centre rod, then a suitable support such as frames must be employed.

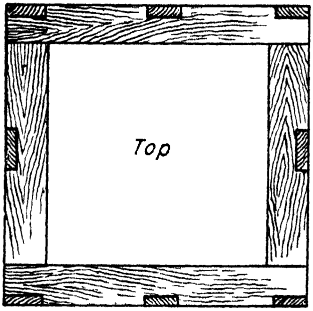


FIG. 31

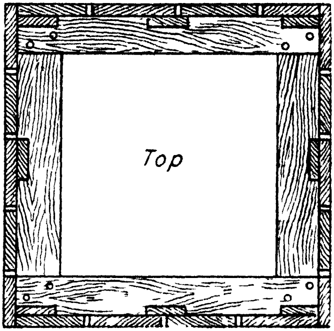


FIG. 32

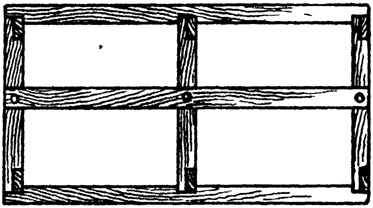


FIG. 33

A similar form of pattern body to that we have just been considering is shown in Fig. 33, but in this case the frames are vertical in the moulding position.

BARRELS

Staved cylindrical patterns are usually called barrels. Fig. 34 shows a suitable barrel for medium-sized and small work. The staves should not be less than 1¼ in. thick at the thinnest part, nor more than 4½ in. wide.

The narrower the staves the more localized is shrinkage or swelling. The distance between the grounds, and this applies to all barrels, should not exceed 18 in. If the distance is greater, there is a possibility of the staves yielding when the pattern is rammed in the sand. The grounds of the barrel, illustrated by Fig. 34, are of two thicknesses of timber crossed, and should not be less than 2½ in. The object of the crossed grounds is to guard against the barrel becoming elliptical owing to the shrinking of side grain.

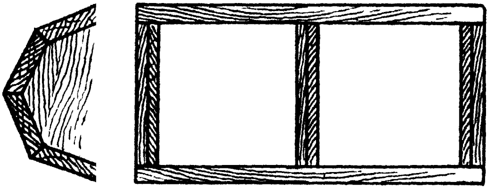


FIG. 34

If a barrel has to be made solid because of being moulded on end—and here it may be said that moulders prefer to cast cylindrical work on end, although it is not necessarily moulded on end even to do this—distance-pieces have to be fitted between the grounds. If the barrel is small, two plates crossed one into the other do very well, care being taken to keep both plates sufficiently off the centre to allow the lifting rod to pass through the barrel. Half-lapped frames have to be used if the barrel is other than very small. When there is a middle ground, either distance frames have to be made carefully and set to lines between the grounds, or the frames are made the full distance between the two end grounds and segments are fitted between to support the staves.

There is frequently a tendency to make patterns very heavy. It is a mistake to suppose that weight means strength, but it is equally fallacious to suppose that a flimsy pattern spells economy. Patterns which are so lightly constructed that, when the mould is rammed up, they become locked in the sand, are not satisfactory. The best patterns are those which are constructed as lightly as possible commensurate with strength.

Figs. 35, 36, and 37 show alternative methods of building a dome. Fig. 35, which is a plan of a skeleton pattern, is certainly the quickest method, but Fig. 36, which is a front elevation, is the better pattern. The method of jointing timber illustrated by Fig. 37 is very suitable for patterns which are too small to be built segmentally. Very few shops adopt this method of jointing, which is undoubtedly the best for much work that is done in pattern shops. The more common but less satisfactory method is to joint the timber parallel to the joint of the pattern.

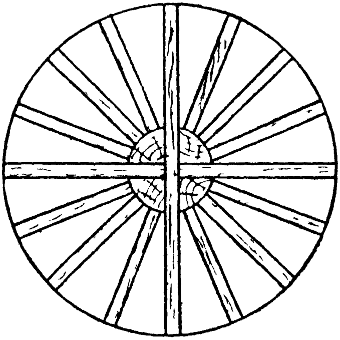


FIG. 35

A very common pattern is the large through valve, and if such a pattern is built in halves so that all joints will be vertical in the mould and from end to end, it gives never-ending service. It takes more time to construct, of course, because there are more joints. It is a very suitable method of building solid work on which much carving has to be done, because if the various thicknesses of timber are joined " back to back," that is, with their contiguous annular rings tangent to each other, it is not necessary to use screws for fastening purposes ; at least, not before the pattern is quite finished.

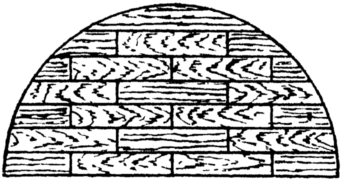


FIG. 36

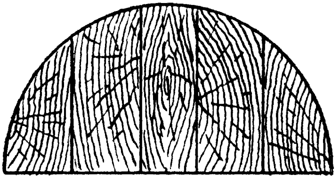


FIG. 37

BOXED-UP WORK

In many pattern shops there is a great deal of boxed-up work—work, that is, which is of square or rectangular shape and too large to be made solid. Sometimes the core is made from the inside of such patterns, and it may be necessary to make open frames similar to Fig. 38. The open frame does keep a large pattern solid, light and strong. Some pattern shops favour plates of two thicknesses crossed, like Fig. 39, to half-lapped frames, but they are seldom as satisfactory either from the pattern-maker's or the moulder's points of view. When a plate 8 ft. or 10 ft. square and ½ in. thick has to be made, however, it is somewhat difficult to make a half-lap open frame of the requisite strength, and the crossed construction may be preferable. It is more convenient, also, if many details have to be fastened to the plate, as it is not always an easy matter to make a frame to give a bearance for various ribs and bosses. When a plate is very thin and screws cannot grip, lead rivets make a strong plate. Attention may be drawn to the open joints. Open joints prevent a pattern from being distorted because they allow the parts of which it is composed to shrink or swell without overall sizes being affected more than that by which one piece varies. We see at Fig. 40 a plan, and at Fig. 41 a joint view of a stern post casting which does not offer much choice of method. One cannot imagine a solid pattern and core-box being made for such a job, because the shape is changing from one end of the casting to the other. The main outline only is shown at Fig. 40, in order that it may be quite clear to the reader. This is a very expensive pattern to make, but there is no other satisfactory method of construction. It is not possible to make it by the skeleton method, and a core-

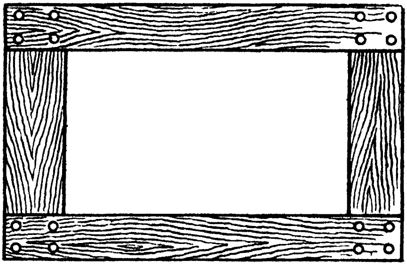


Fig. 38

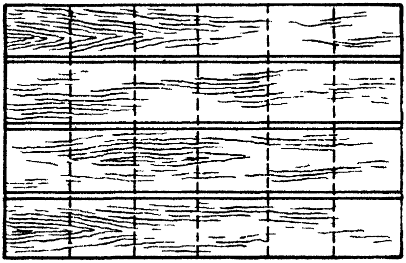


Fig. 39

box, as we have said, is out of the question, as it would involve considerable additional cost.

PATTERNS SIMILAR TO CASTINGS

Patterns may be made that define the full shape of required castings. As a rule they are used for work of a simple character when cores are unnecessary, and may involve inaccuracies or additional labour. The most important advantage of making a pattern that is a counterpart of the casting is that metal thicknesses are assured ; with a solid pattern and core-box—and especially so if the cores are intricate—there is always the possibility of error. Only a small proportion of

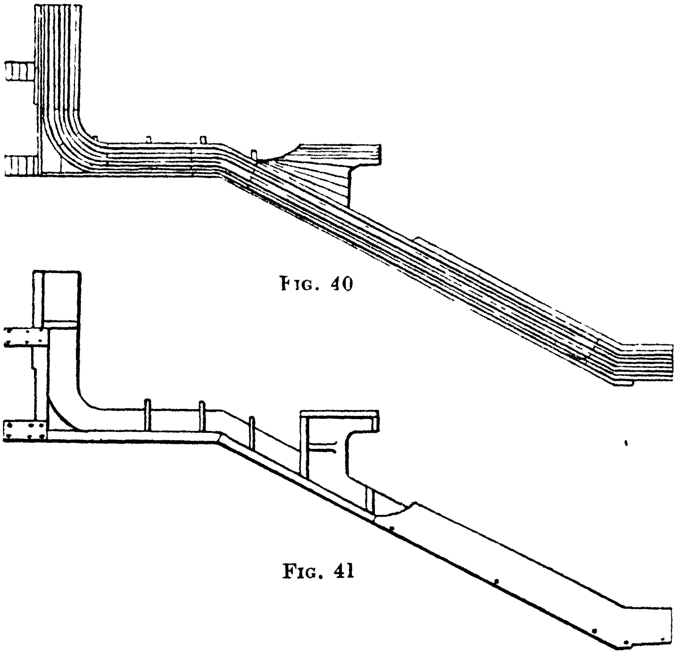


FIG. 40

FIG. 41

patterns can, however, be made as "shell" patterns; often when it would be practicable to make a shell pattern it is not advisable to do so because the pattern would be too fragile, and would consequently be liable to distortion and would not be durable.

It is sometimes convenient to make a pattern that is a model of the casting if the casting fits on to an irregular shape. At Figs. 42 and 43 is shown a casting designed to fit on to the hull of a ship. For cheapness or effectiveness a shell pattern is better than a solid pattern and core-box, because of the awkward flange face. Only approximate particulars would probably be given on the drawing for the shell flange, *A*, Fig. 42, the job being set down from templets or moulds supplied by the moulding loft, the object being to have the flange *B* vertical when in position on the ship. After the work is set down two sets of templets would be made, the one set to be used when building the body and the other set to be used when building the flange *A*.

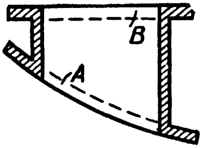


FIG. 42

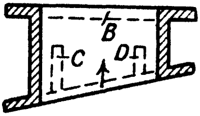


FIG. 43

Considering the flange *A* first, the positions of the templets are set down on the drawing board as *C* and *D*, Fig. 43, the other view of them being as in Fig. 44.

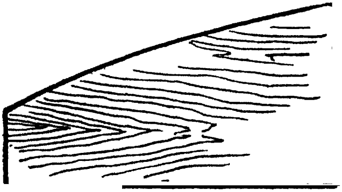


FIG. 44

The flange should be built on top of the templets, which have been fixed to a level board. If it is of large diameter—say, over 2 ft.—strips of timber 3 in. broad will be satisfactory; but if it is a short radius, it will be well to have them narrower. They should be kept as broad as possible without it being necessary to plane them concave and convex. Fig. 45 illustrates the method of building the flange on the templets or grounds. The segmentally-built body of the pattern would present no difficulties. When sufficient laminae of segments have been built, a templet like *A*, Fig. 46, would be made consisting of legs screwed to a straight-edge. The templet would be made to ride on the shape-defining templet *BB*, and hermaphrodites would be employed to obtain a flange-fitting line, the pattern being subsequently planed off to this line and the hermaphrodites again brought into use to draw the flange the parallel width from the body. The inside of the flange can be cut out with either the jig or pad saw. Making and fixing the top flange is a simple matter. Usually a job like this has fitting strips, but they need not occasion much trouble. They should be got out as segments, broader and thicker than required. Slippers or wedges can be inserted at the ends to raise the segments from the flange, while hermaphrodites are used to draw a line on them parallel to the flange. The segments can

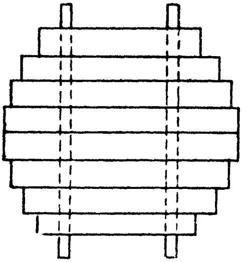


Fig. 45

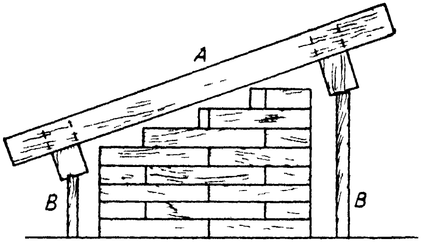


Fig. 46

then be finished by saw and spokeshave, and gauged to a thickness. It is advisable to screw them in position and draw the diameter on the face. They can then be unscrewed and finished off, and replaced. The pattern can now be sandpapered. and any ribs or bosses and fitting strips screwed on.

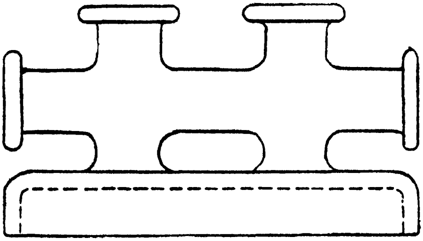


FIG. 47

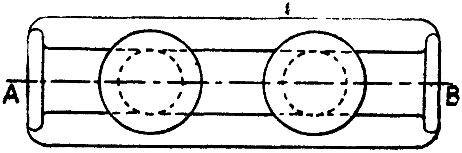


FIG. 48

PATTERNS POSSESSING A SOLID EXTERIOR INVOLVING CORE-BOXES

The majority of patterns are of this class, defining the external shape of castings, cores being necessary or expedient to form the inner shapes. It is proposed to describe representative patterns in this class. At Figs. 47 and 48 is shown a common type of bollard casting, in which the base is deep and cored out, but the bollards are solid. Sometimes these are cored out, but it is not the invariable practice. The pattern for this casting might be made in one of several ways, but whichever method is decided upon, the pattern should be jointed on the line *AB*, Fig. 48. One method of constructing the pattern would be to box up the base to the joint, and, after finishing the top part, fasten the two portions together with long screws from the base into the bollards. The advantage of this is that it readily allows of alteration on some future occasion. A disadvantage, however, is that this form of pattern is not sufficiently rigid, and it is so heavy that, if roughly handled, it may come apart.

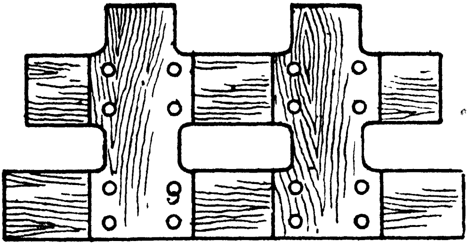


FIG. 49

The better plan would be to make two half-lapped joints, as shown in Fig. 49, and build on them. The cross-pieces would be left sufficiently wide to allow of the fillets being cut out, but if wide timber were not available this is not actually necessary, as square corner blocks could be glued in, and the fillets cut after the bollards had been built on top of the plates. The boxed-up base is shown in the view of the finished pattern in Fig. 50. It would be made of fairly heavy timber, say, 1½ in. to 2 in. thick, and with even thicker ends, which would allow the large radius to be taken off without weakening the pattern. As in all boxed pattern work, the top ought to slip inside and rest on a recess about ½ in. in width.

Some pattern-makers would prefer to make the longitudinal bollard one long-lagged barrel from end to end, and joint short barrel pieces on to it for the cross or vertical bollards. This method is advisable in the absence of joint plates, but it does not make a really first-class pattern, in that all the fillets have either to be fitted round as segments and gouged in place, or left to the moulder. In Fig. 50 is seen a much better way. Solid square blocks *A A* would be planed up large enough to take the fillets. The diameter of the bollards, which might be anything from 6 in. to 12 in., would be drawn on each of the faces, and neatly finished with paring chisel and gouge. They would not be screwed on the joint frames until the pieces *BB* had been screwed to them. These pieces might be turned and the thickness of the joint plate afterwards cut off at the "pattern-making" machine. When these combined pieces had been screwed to the joint plates and also from the face of the base piece, the barrel portions would be made and put into position. Generally, if the diameter of these barrels is more than 8 in., it is well to use staves; below this diameter they can generally be made solid.

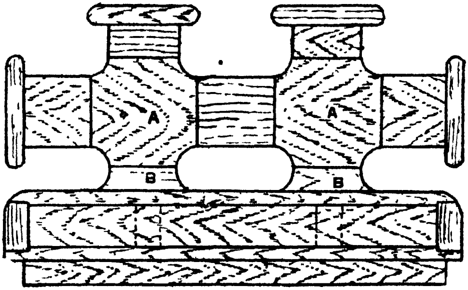


FIG. 50

The flanges on the faces of the bollards would be easily turned. The prints on the base would be about 3 in. thick. When the base is being boxed up, thick pieces of timber should be fitted in opposite the position of the bollards, in order that the screw holes can be bored through them. If this is not done difficulty will be encountered in inserting the screws, and they will not have the necessary holding power. The pieces need not be checked into the sides of the base, as they cannot move or be knocked out of position. They act also as grounds for the base. The small fillet behind the flanges can quite well be rubbed by the moulder. An ordinary framed core-box may be made for the base core, and the fillets here also can be ignored by the pattern-maker. It is not often that a large number of castings is wanted from these patterns, or it would certainly be desirable to attach all fillets in the pattern shop.

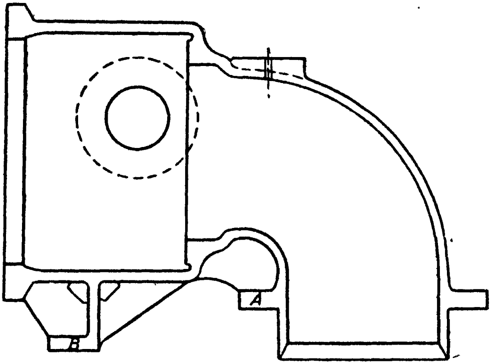


FIG. 51

At Figs. 51, 52, and 53 is shown a large boiler main stop valve, with a single-valve chest. In addition to large-scale views, a number of thumb-nail sketches are usually given, which show the arrangement of the branches. These sketches may be marked " boiler one," " boiler two," etc. Whether the pattern-maker

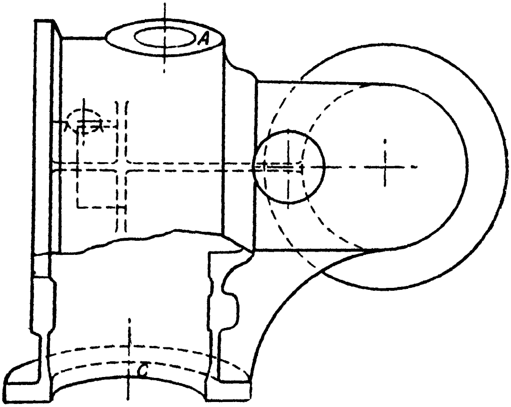


FIG. 52

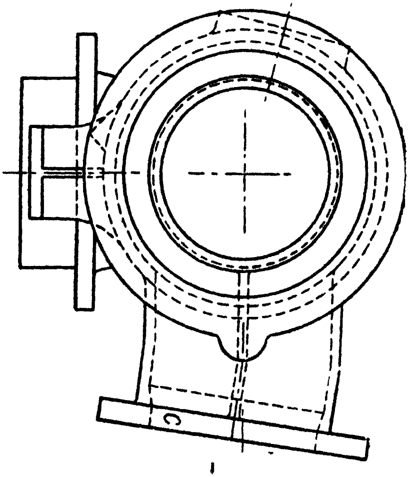


FIG. 53

alters the pattern to make it conform with the requirements for each boiler before it goes to the foundry, or has it returned for alteration after each casting is made, is purely a matter of shop practice. It is generally advisable to mark all change pieces.

The valve is a comparatively simple one, but there are several alternative methods of constructing the pattern. Much depends upon whether many castings are required, because it could be made either skeleton or solid. In any case, however, two joint plates are necessary, and these should be constructed as shown in Fig. 54. The plates might be 1¼ in. or 1½ in. thick, and should be open jointed. It will be noted that the joint plates are made to fit behind the flanges; thus the flanges are complete half diameters.

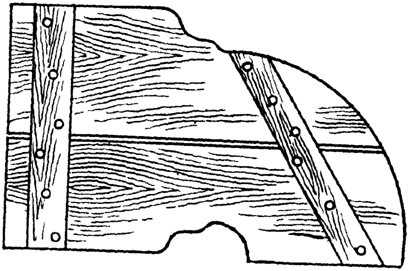


FIG. 54

The construction of a solid pattern for a stop valve of this kind is an interesting piece of work. Joint plates must be either segmental, or, what is equally satisfactory, built with longitudinal staves resting upon two rings fitted on the bridge piece, and the cover flange in a similar way to that already described for a skeleton pattern. When this method is adopted, a jig can be conveniently made for the planing machine, and the staves planed to the correct taper, so that no hand fitting is necessary. Another method would be to build this straight body part with grounds and stays. A view of such a construction, showing the cover flange fitted over it, is illustrated at Fig. 55.

The above may be made solid in one or two different ways. It may be jointed up of thicknesses of timber, planed, and then shaped with templet. This is, of course, the usual method of constructing small bends, but it is not altogether satisfactory for bends of the size being described, and it is certainly an extremely wasteful method. There is no reason why large bends should not be built segmentally. Fig. 56 shows a plan and section of a built bend branch. If ordinary care is taken in getting out the segments, which ought to be ground to shape on a sander, before being built, it will scarcely be necessary to use the templet at all. The joint lines should give the correct radii. This is a very strong method of construction, and there is no liability whatever for the pattern to warp. Moreover, it does not take longer to construct a large bend in this way than if it were made solid. In such a pattern as that under consideration the use of joint plates can certainly be obviated by running a batten diagonally across the joint after screwing the bend to the straight body with pocket screws, but this is not as rigid a construction as when the plates are used, and a pattern of this size is

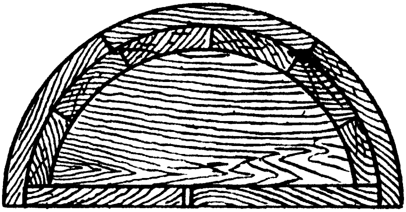


FIG. 55

liable to be roughly handled going to and from the foundry, as well as when it is in the sand.

As the foot, *B*, Fig. 51, is on the joint of the pattern it presents no great difficulty. Some consideration has to be given, however, to the branch, and it is not simply the difficulty of coring but the delivery of the pattern from the sand that has to be considered. Fig. 57 shows one method that could be adopted. A symmetrical bend might be made of this branch which could be drawn from the mould with care, but the method of joining the branch is preferable. The moulder would use the loam cake for the flange and

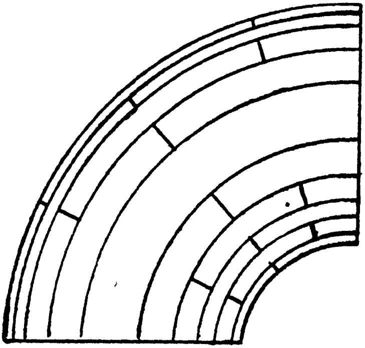


FIG. 56

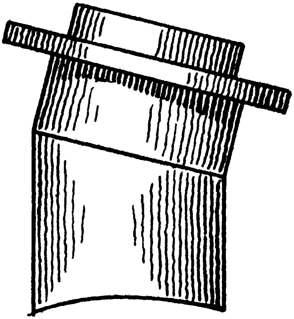


FIG. 57

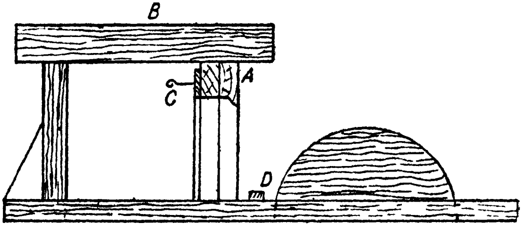


FIG. 58

top part of the branch, while the other part would come away with the main body.

With regard to the construction of the cores, for this valve the main body and bend core would either be made in a core-box or on a plate, and a separate core-box would have to be made for the top branch; a check is cut from the print and the corresponding piece inserted in the core-box. Fig. 58 shows a very usual form of plate for the main core. In some shops a solid plate would be made and the core swept on top. When several cores have to be made it is much better to make an open frame about ⅞in. thick with the shape carefully cut. A bridge piece *A*, Fig. 58, is necessary to support strickle *B*, which defines the core, and it also serves as a support for the valve seat *C*. The bend may be swept with a board revolving on a dowel, as shown in Fig. 59, or a guide piece *D* may be screwed to the frame and a check cut from the board to enable it to ride over this guide piece. Whether a plate or frame is used, it is necessary to reverse the parts to complete the core.

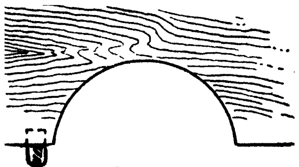


FIG. 59

SKELETON PATTERNS

A skeleton pattern is one which is made partly of wood and partly of sand. A large variety of work that is not of a repetition kind is made by the skeleton method, including practically all pipes over 4 in. Fig. 60 shows the plan of what is commonly called a "Y"-piece with a tapered bend *A*. The pattern should be in halves, and two plates would be made and dowelled together. The main plate, Fig. 61, would be made first. The two legs *B* and *C* and the bend *A* would be fixed to the main plate by bars screwed on the back. These plates would be $\frac{7}{8}$ in. or 1 in. timber, and dowelled before being finished off. Some craftsmen finish off the plate to the backs of the flanges, while others check the flanges over the plates. The one method is equally as good as the other.

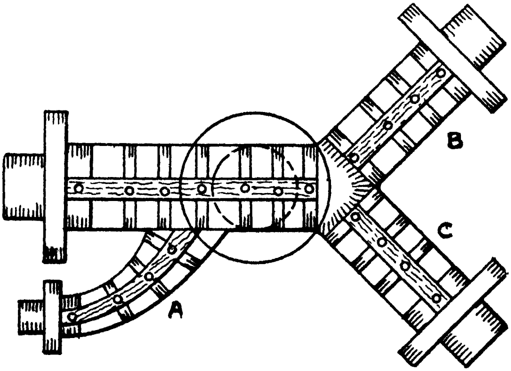


FIG. 60

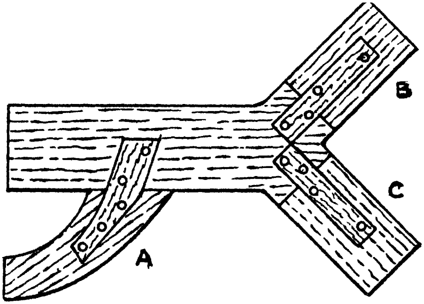
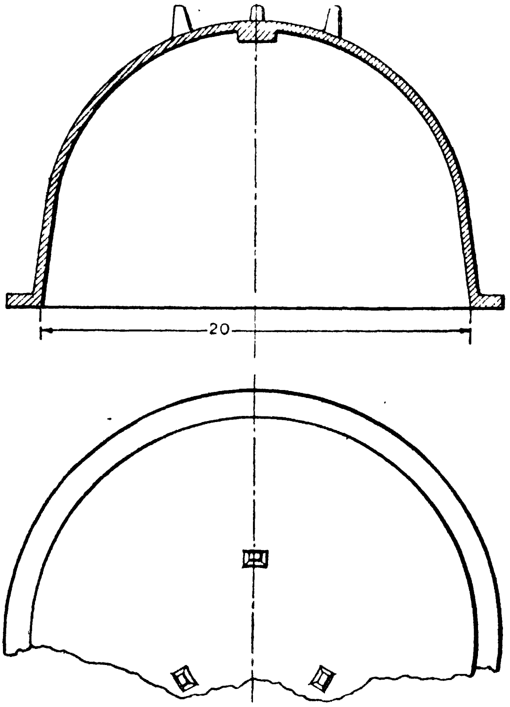


FIG. 61

A templet would be made for the grounds, and these should be kept about 3 in. apart. Two screws should be used for each ground. The quickest method is to stitch all the grounds on with panel pins or sprigs, then turn over and screw. For the bend, grounds would have to be made to suit the changing diameter. The prints for such a pipe ought to be 2 in. or 3 in. thick. It will be seen from Fig. 60 that the grounds do not make a



FIGS. 62 AND 63

satisfactory finish at the junction of the branches *B* and *C* to the body. Whenever it is impossible clearly to define the shape by means of grounds, as in this case, it is good practice to fit a solid block and cut the shape with chisel and gouge. The top branch *B*, no matter what length it is, should be made solid that it may deliver easily from the sand, the flanges being dowelled on. To stiffen the whole pattern, strips would be nailed into the oblong recess at the top of the grounds and finished off on the circle with the spokeshave. The edge of the plates can also be spokeshaved off to the edges of the grounds.

The mixing pan shown at Figs. 62 and 63 is a type of design that can be conveniently made by the skeleton method. The thinness of the metal precludes the desirability of constructing a shell pattern, either solid or skeleton. It would be possible to make a solid shell pattern, but it would be extremely difficult to do so, and, when finished, it would be very fragile.

As shown at Figs. 64 and 65, a substantial base is built of laminae of segments. The print may be about 2 in. thick; indeed, less than 2 in. would do, because it is not required to support the core. If the pattern were much larger it would be wise to build it with a plate and row of segments, but for a 20 in. diameter it could be made solid. The flange would not be built on top of the print, but it might be advisable, because of the awkward design, to screw it on the flange before erecting the frames. The actual flange is made of one thickness.

The vertical frames *A* and *B* would be 1¾ in. or 2 in. thick, and the rails 3 in. to 4 in. wide. One frame would be made the full width, while two would be half this width less half the thickness of the frame against which they would butt. The crown, which rests on the frames, would, as will be seen from Fig. 64, be made from a solid thickness with a ring of segments on the underside. This ring is indicated by the dotted lines in Fig. 65. The section pieces should be made of timber about 2 in. thick. If a thin templet is first made and tested on the drawing-board, these pieces can very quickly be sand-papered to shape after being sawn. The number required is easily determined, and two screws should secure these pieces quite firmly. A part plan view of the finished pattern is shown at Fig. 66.

Fig. 67 represents a section of a pattern of a large cast-iron cover or door. Circular patterns of this kind are nearly always made with radial-shaped defining pieces fitted between a centre boss and the flange, and it is necessary when making the boss and flange to have a check so that the radial pieces will have a satisfactory landing. The centre may be turned the exact thickness of the metal. The flange is in three thicknesses, and instead of allowing $\frac{3}{16}$ in. or $\frac{1}{4}$ in. on the inner and outer diameters, as when turning, the segments may be finished, and when the whole job is built very little cleaning would be required. The flange would have to be built on a very level board. The difference in diameters between the centre boss and flange may necessitate the pieces being tapered at the inner diameter.

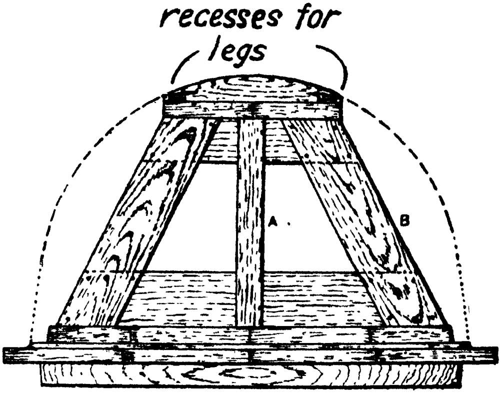


FIG. 64

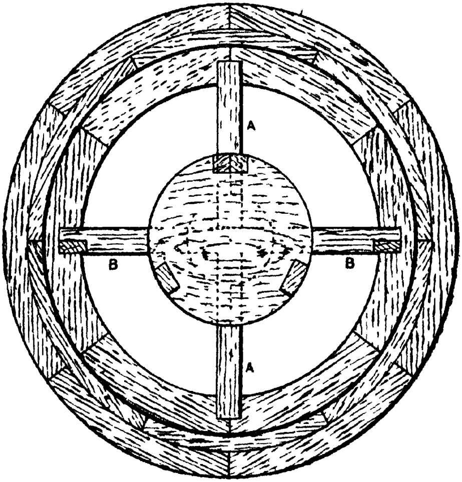


FIG. 65

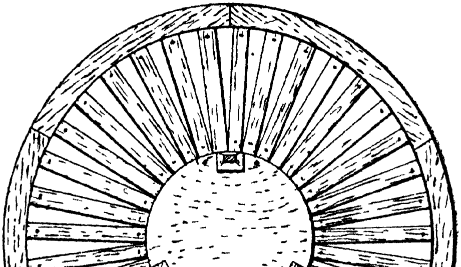


FIG. 66

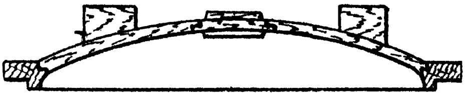


FIG. 67

In building such a pattern as that being considered, it is necessary to lay down every detail on the drawing-board. The flange would first be set in position and then the centre boss temporarily screwed to a support consisting of two pieces of timber 12 in. to 18 in. long and about 2 in. thick, with the heights taken from the drawing-board. The centre boss being now set on top of the cross, pocket-screwed to the drawing-board, squares would be set to a circle on the drawing-board corresponding to the outer diameter of the boss indicating its correct position, which could also be tested with the templet from which the section pieces have been cut. The section pieces would now be built in position, care being taken that they bed properly on the landings; otherwise, when the supporting cross is removed, the pattern would not have retained its shape.

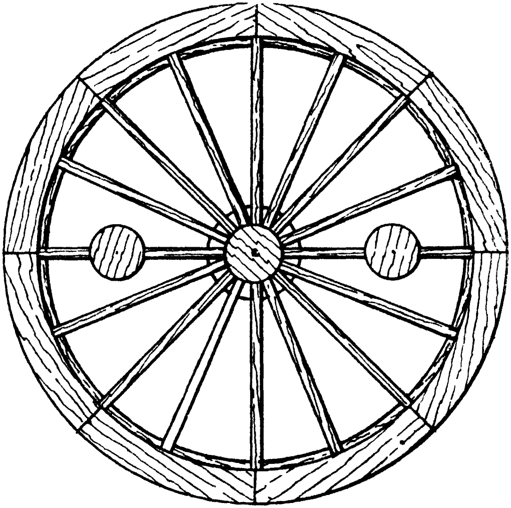


FIG. 68

All that now remains to be done is to make and fit the manhole facings. Fig. 68 is a plan of the finished pattern.

SWEEPING BOARDS

Sweeping boards are used to sweep out moulds in sand or loam and to form sand patterns. It is only economical to use sweeping boards when few castings are required, because, while less labour and material will be needed in the pattern shop than when patterns are made on the spot, the foundry costs are considerably higher. Circular work is especially suitable for sweeping, and, although there are exceptions, it is seldom advisable either to sweep out a mould or to make a sand pattern for work that is less than 2 ft. in diameter.

Sand barrels may be swept up for cylindrical castings, and on this barrel, flanges, ribs, bosses, facings, and other parts made of timber will be fitted by the pattern-maker. When making boards for a sand mould or a loam mould it is often unnecessary to make a special working drawing ; the job is carefully drawn on the actual sweeping boards, and the metal thicknesses are clearly shown on this, thus the moulder knows exactly what is required.

For circular green-sand moulds, a bottom board sweeps out a mould on which the metal thickness is formed with sand, thus forming a dummy pattern for ramming the cope. In sweeping loam moulds, two boards are used, which actually sweep out the entire mould. When making boards that will be bolted to the tail piece of a perpendicular spindle, one edge is planed straight and square, this being kept as the top edge from which all sizes are gauged, the object being that when the board is being set in the foundry a level is placed on the top ; obviously, if one diameter is correct all the others will also be correct.

Fig. 69 represents a steam cylinder cover, while Fig. 70 shows the bottom board necessary, and the thickness of the metal marked on the board to guide the moulder when closing the mould is clearly shown. It is necessary to sweep a bearance to set in the ribs, hence a piece of wood *A* is attached in such a manner that it can be easily removed when the bearance is swept up. To cut out the portion of the mould to secure clearance for the steam port a piece *B* is attached.

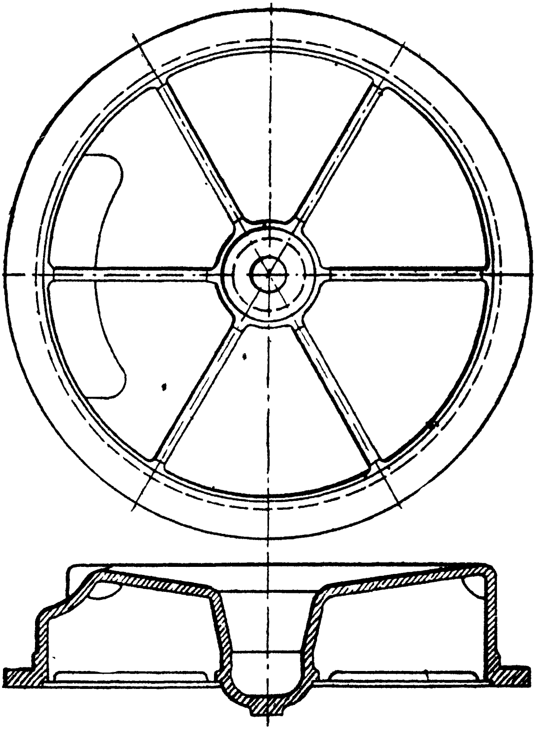


Fig. 69

The top board is shown at Fig. 71, with a loose portion screwed on for the steam-way clearance. It will be noticed that these boards form a spigot joint, so that the drag and the cope fit accurately together. Sometimes a "feeler" joint is made, as indicated by the dotted line at Figs. 70 and 71. The centre line is usually left on sweeping boards, so that they can be cut back to fit whatever diameter spindle is being used. A gauge stick (Fig. 72) would be made to the flange diameter, while two templets similar to Fig. 73 would be made to give the moulder the correct shape of the steam-way clearance; they would be marked top and bottom, and centre lines would be drawn on them.

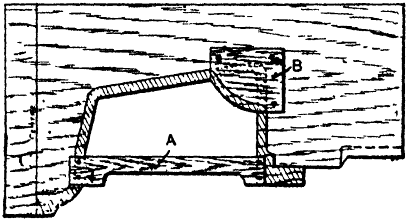


FIG. 70

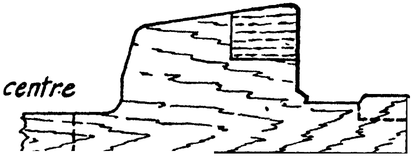


FIG. 71

Five ribs would be made to the full lines in Fig. 73 and one to the dotted lines, and they would be cut about $\frac{1}{8}$ in. clear to allow the sweeping board to pass over them; slots should be cut (to the moulder's instructions), as at *A*, Fig. 73, to permit the moulder's grid to pass through.

A large cylinder, like that shown at Figs. 75 and 76, could be made by means of a loam pattern or by sweeping out a cope. It is common practice to-day to make a loam pattern, but a suitable cope board is shown at Fig. 77. Such a board would be made of timber $1\frac{1}{2}$ in. thick. The centre of the mould is indicated by *CC*. In making the board, the vertical and horizontal pieces would be half-lapped together and then the cope outline drawn. The finger or bearance pieces for the ribs would be made of hard wood, about $\frac{1}{2}$ in. thick. When sweeping out a cope the steam chest is set in position before the actual building of the cope is commenced. The board for sweeping a loam pattern is shown at Fig. 79. The stiffener used to support the board is preferably introduced as indicated in the sketch. The extending pieces *A A* are to sweep recesses in the pattern for convenience in setting the ribs. It must be understood that a sand pattern carries all the details as a wood pattern does, but it cannot be moved conveniently like a wood pattern. The shoulder *B* is to take out a recess in which a top flange can rest. To save fitting up the crown of the cylinder in the foundry a complete half-lapped frame flange might be made for the top with the stuffing box

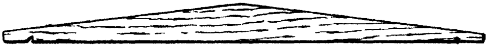


Fig. 72

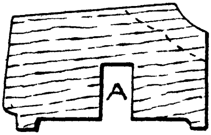


Fig. 73

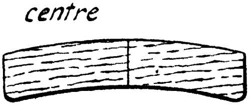


Fig. 74

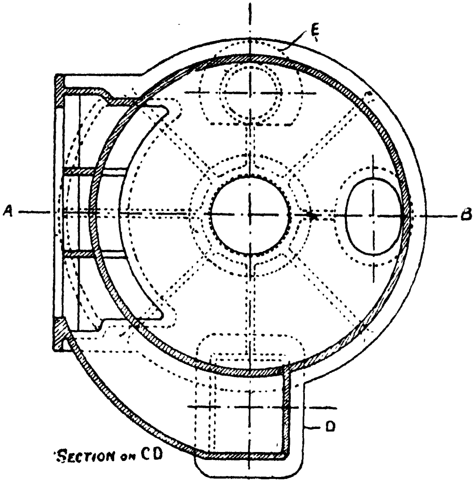


FIG. 75

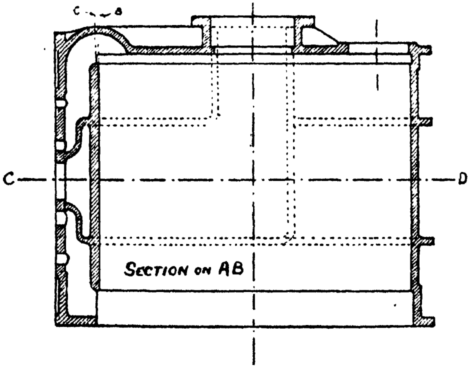


FIG. 76

and the ribs screwed to it, and this set on the sand block. Alternatively, a recess could be swept out of the

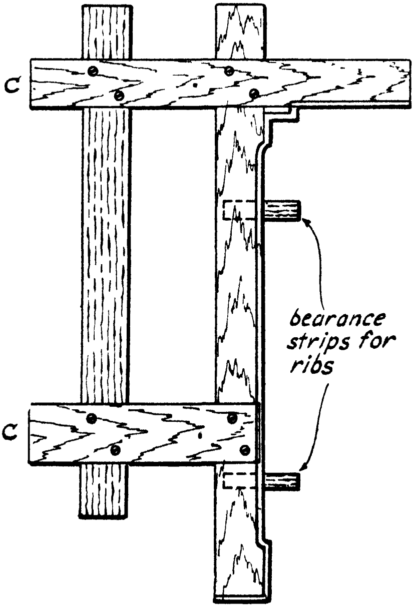


FIG 77

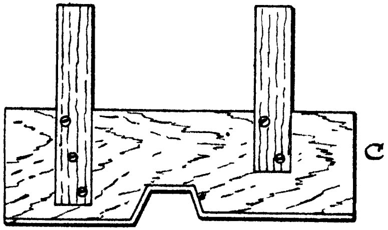


FIG. 78

top of the sand pattern into which the stuffing box would be located, while, if the stuffing box was short, it could be swept with the loam boards. Fig. 81 shows a sand pattern swept by the board described, the bearance having been swept up by means of a seating board (Fig. 80), which also forms a print. The battens on the seating board serve the double purpose of strengthening the board and affording facilities for securing it to the tail piece.

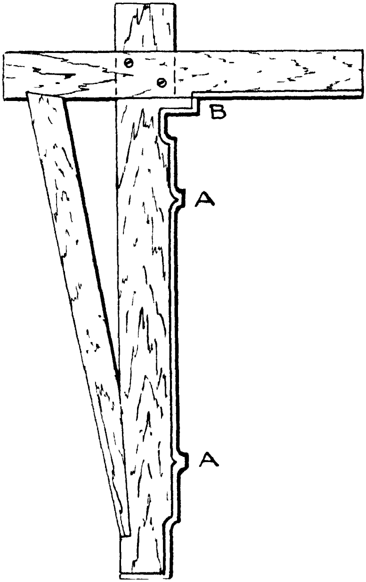


FIG. 79

When setting the boards described, gauge sticks are necessary. A board is made for the core, which is similarly constructed to the pattern board, while other boards have to be made for the stuffing box core and one for the port of the steam-way. It is customary in some foundries for the pattern-maker to test the accuracy of sweeping boards after the moulder has bolted them to the spindle and before he has started sweeping out the mould.

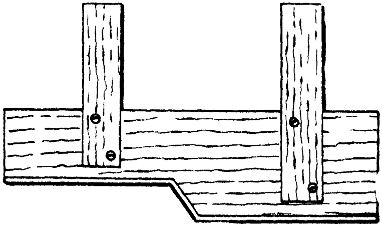


FIG. 80

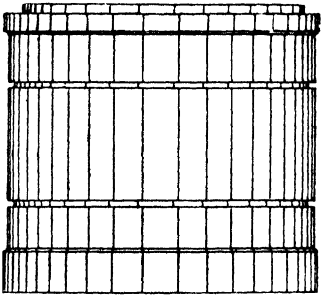


FIG 81

COMPOSITE PATTERNS THAT ARE PART SKELETON, PART SOLID

For repetition work, patterns should always be made solid, and first cost is of less importance than accuracy and durability. The additional cost of making a first-class pattern is regained in the foundry and the machine shop. Patterns for automobile work must be accurately made of best quality timber, while, at the other end of the scale, are the patterns made in a millwright's shop from which only one or two castings will be made.

Many patterns can be made involving a combination of solid and skeleton work. Fig. 82 illustrates a common type of large double steam-valve chest. As a general rule it is better to make patterns of this type solid, but if wanted in a very short time, or if the use of a lathe were not possible at the moment, the ends may conveniently be made by the skeleton method. Fig. 83 shows the best way of boxing-up the straight part of the body. The joint plates should be made to the outward shape, and two or three grounds screwed to it and lagged over. The branches for these valves are usually short, and should be made solid. It is not necessary to make the joint plates to carry the flanges. Top branches should be solid, and it is wise to make any branch solid if part of it has to be left loose to get it from the mould.

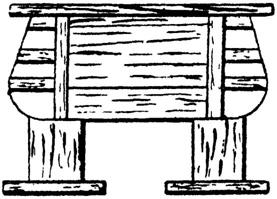


FIG 82

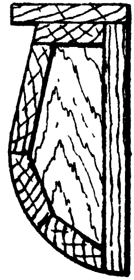


FIG. 83

A pattern of a different type is shown at Figs. 84, 85, and 86. It is a bend pipe with a large fillet at one flange, the core inside being rounded off to a large diameter. For a composite pattern, as shown at Fig. 84, two joint plates of 1 in. or 1¼ in. timber would first be made. These would be made of boards placed edge to edge, or of half-lapped frames. These plates would be dowelled together and the shape finished before starting to build on them.

The segmental method of construction is quicker for the straight lengths than the grounds, and more suitable than a barrel piece, owing to its being so short. The curve is made skeleton because, if made solid, it would entail a great deal of work shaping it at the bench.

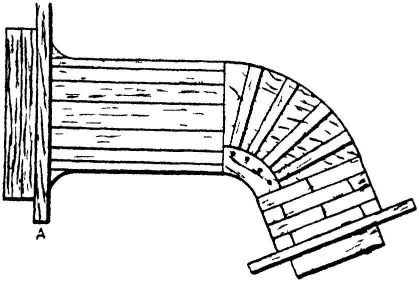


FIG. 84

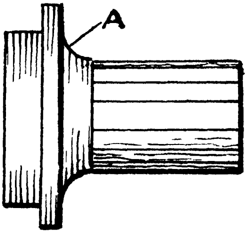


FIG. 85

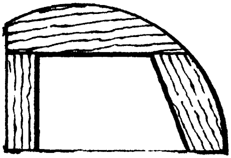


FIG. 86

The solid block at the inner curve, while not really necessary, is advisable, because when a number of section pieces converge towards a centre as in this case, unless the pattern is very large, it is not an easy matter to obtain a satisfactory shape.

A solid fillet in segments might be made, as at *A*, Fig. 85. If this were done, the quickest way to shape it would be to screw the segments on a face plate, leaving the inner diameter about an inch smaller than the diameter of the barrel, and band-sawing them afterwards to fit the barrel. The best method would be to make the barrel shorter and turn a fillet piece in the lathe, the thickness of the joint plate being cut off after it is turned.

The flanges and print of this composite pattern would be best carried to the joint, the centre plates being made to fit behind the flanges. It would be advisable to have a fairly thick print at the large fillet end, so as to leave a body of sand in the core beyond the fillets.

CORE-BOXES

There are usually as many different ways of making a core-box as of making a pattern. For repetition work, well-made solid core-boxes are required, but for "one-off" jobs a core-box may be dispensed with altogether, and a board or frame with strickles substituted by which the moulder can sweep a core. When possible, a core-box should be jointed similarly to the pattern. To reduce production costs, when two halves of a core-box are the same, or practically so, a half core-box is made from which two half cores are obtained and fastened together. To place a core in its mould it may be necessary to make it in several parts ; the alternative, in such a case, to making several boxes is to make one box and leave it to the core-maker to make divisions with the aid of paper and tin, but this is not good practically, and is only excusable in circumstances where speedy production is necessary.

Much that has been said about pattern construction is equally applicable to core-box construction. In large boxes, the bottom and sides of which have to be made of several widths of timber battened together, joints should be open. There should be as few loose pieces as possible, and when some are necessary, except for "one-off" jobs, they should be dovetailed or dowelled in position in order that they may be accurately replaced. It is very important that in rectangular cores as much taper as possible should be allowed, and this applies also to ribs that are at right angles to the horizontal joint of the box.

In cutting half-diameter core-boxes a templet may be dispensed with, and a set-square used as shown at

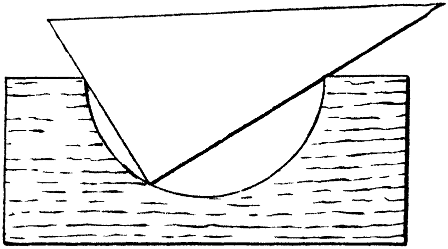


FIG. 87

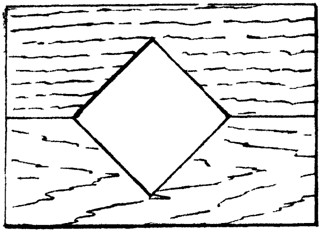


FIG. 88

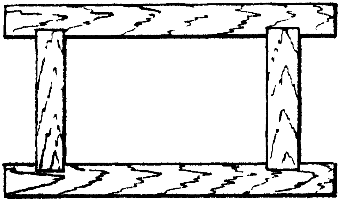


FIG. 89

Fig. 87. It is always easier to cut a core-box across the grain of the timber than with it. In making a solid core-box in two halves, the two halves should be accurately planed and dowelled, the design of the core drawn on the joint faces, and the centre lines carried down the outside faces. It is better to use too many templets than too few.

There are several methods of making small square or oblong cores ; when they are short a core-box like Fig. 88 may be made ; if a considerable number of cores be required, three or four cores might be cut from one length of timber. Fig. 89 shows one of the commonest forms of core-boxes ; it is a frame, open top and bottom. The sides are screwed to the ends. The core-maker rams up the core on a plate, strickles off the top, and loosens off diagonal corners of the box. Frame boxes of this kind are made for all sizes of rectangular cores, and they can also form an outer framework for building up complicated core-boxes or for enclosing a circular core as at Fig. 90, which is simply a frame with

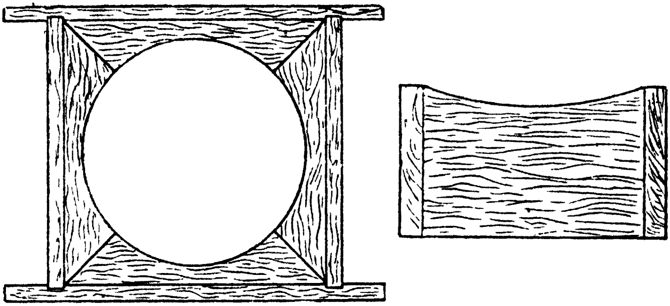


Fig. 90

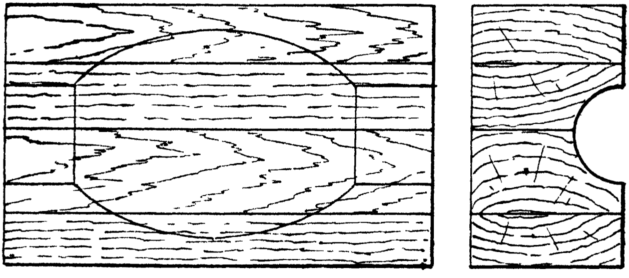


Fig. 91

mitred pieces screwed inside. The same principles of jointing timber are applicable to core-boxes as to patterns. Fig. 91 represents the best method of building a medium-sized solid core-box.

To reduce pattern-making costs, a mould may be made entirely without cores. Fig. 92 illustrates a large-built sheave wheel with the boss and rim as castings.

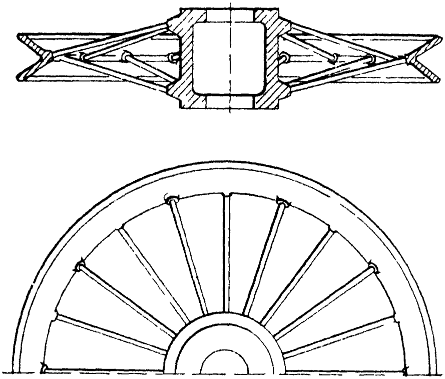


FIG. 92

The boss core-boxes are shown at Fig. 93. The central core would be swept on a horizontal spindle, while the outside of the base would be formed in three cores. The middle core-box is shown at *A*, Fig. 93, and the top and bottom cores at *B*. These circular cores are built of laminae of segments, this being a convenient method of constructing many cylindrical core-boxes. *C*, Fig. 93, actually forms the moulds, and attention may be drawn to the dowelling of the boss. A centre print is necessary, which is built as shown at *B*, Fig. 95. The outer rim is also made of cores, and a bearance board is used for forming a bearance in the sand to receive the segmental cores. This bearance board is bolted to a vertical spindle. Fig. 94 shows sections of

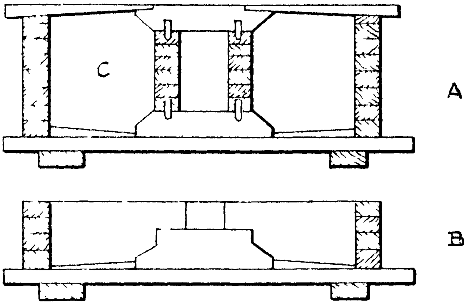
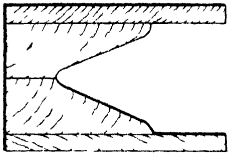


FIG. 93



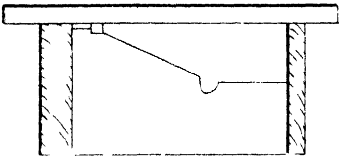


FIG 94

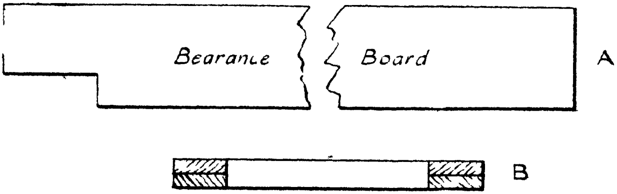


FIG 95

the rim-boxes. The rim core-boxes may be one-sixth or one-eighth of the diameter. Not only is it cheaper to make a segmental core-box, but the cores can be more conveniently handled.

In most cases, when a skeleton pattern is made it is possible to make a skeleton core-box. Skeleton core-boxes are usually composed of an outside frame filled in with section pieces and with a joint plate outlining the shape that may be ½ in. thick. One form of core-box will supply the means for giving shape to the bottom half of a core, and, by attaching runners or guiders on the top surface or joint, the top half can be strickled to form the full core. An interesting skeleton core-box is shown at Figs. 96, 97, and 98, this being for a large valve. The case need not be made the full depth from the joint of the pattern to the branch print, but only deep enough to give reasonable strength to the bottom section pieces. Thus, if the depth were made about 1 in. greater than half the largest diameter of the required core, the case would be quite deep enough. Grounds would be made about 2 in. thick and screwed inside the ends. These would have semi-circular holes cut out about 2½ in. larger than the diameter of the core at the ends. A templet would be made to follow the contour, having the ends checked to suit the grounds. The section pieces would be wide enough to fit against the sides of the case or flush with the bottom, and, consequently, it would be advisable to mark their positions on the drawing-board in order to obtain the different widths.

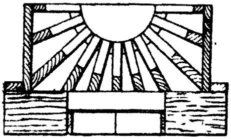
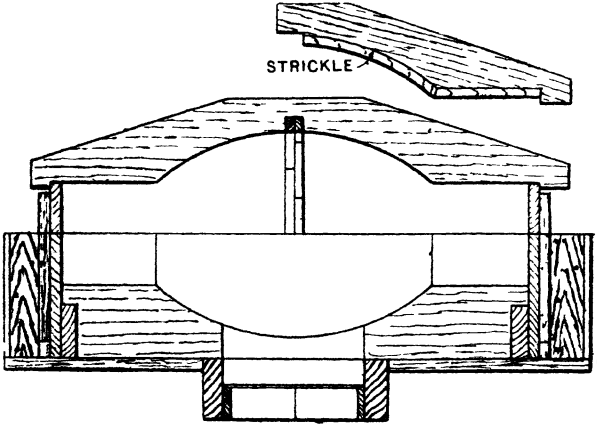


FIG. 96

When the section pieces are cut they are secured to the grounds. Some of these section pieces would need to be cut to form part of the branch core, but before



SECTION AT A-B.

Fig. 97

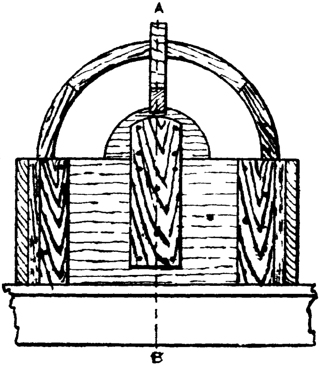
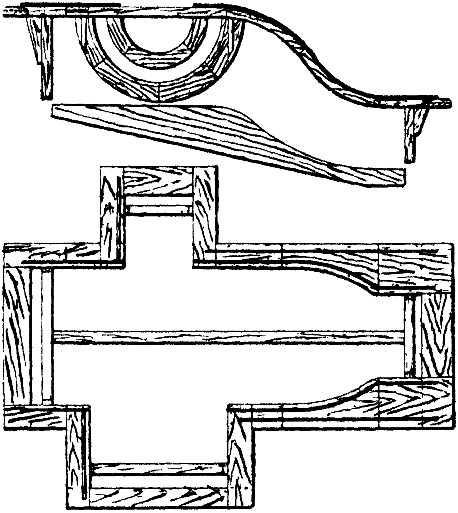


Fig. 98

doing this it would be better to prepare an extension piece to complete the required shape of the branch core. This would be made solid, and not in halves, but a slight taper would be given to facilitate stripping. The shoulder to form the machining strip and core-print would be introduced afterwards as segmental pieces and left loose. When this part of the box has been accurately located and secured to the main box, the remainder of the bottom would be covered in the manner shown in Fig. 97, and the section pieces coming in contact with the bottom secured. They would then be sufficiently rigid to be cut, and thus complete the branch shape.

The ends of the case would carry semi-circular pieces, Fig. 98, projecting from the joint face and forming runners for a strickle, and as these cores are usually too long for a full-length strickle, a centre runner could be fixed to the largest diameter and kept rigid by means of a shaped stay as shown. The one strickle would suffice for each side.

Framed plates are frequently used for making cores and also for sweeping out moulds. When the joint of the mould is straight the work is simple, but with a curved joint it is more difficult. The underside of the frame should follow the joint of the mould and coincide with the centre of the pipe, and it would be necessary to cut bearers upon which the frame can be built. The frame would be about 1⅛ in. or 1¼ in. thick, and the material about 5 in. wide. The curved portion could be made up in two thicknesses, in segmental fashion; segmental pieces the full thickness may be prepared and secured by means of hardwood segmental battens, the inside of these battens being stepped back from the contour of the pipe to serve as a guide for strickles. Instead of using wood to secure the curved pieces, ⅝ in. square iron may be bent to suit the shape, having holes drilled at convenient places in order that they may maintain the requisite shape when secured to the frame, in the manner shown in Figs. 99 and 100. When the frame has been half-lapped and is assembled on the bearers the correct outside shape of the pipe would be formed inside the frame, and this shape obtained



FIGS. 99 AND 100

before the frame is actually secured. The ends would require to project between 2 in. and 3 in. beyond the flanges to give room for sweeping core-prints. Top guides are necessary in order to sweep the top shape of the pipe, and these set back from the inside contour of the frame a distance of about $\frac{3}{4}$ in.

The frame is the principal part of the pattern-work, and considerable care would be necessary in its formation. The half-flanges to be secured to the underside of the frame would be built segmentally, and each would be cut to the correct outside diameter and the diameter of the bore which it represents. Brackets are cut so that when the flanges are secured in their respective positions they may be held at the required angle with the centre. The flanges would be so secured that the screws are accessible from the top of the frame, although the brackets could be fastened to the flanges so long as the frame could be lifted clear after the mould has been prepared by simply releasing a few screws. A temporary stay fixed between the main flanges, as shown in Fig. 99, gives increased rigidity to the frame until it is set on a bed in the foundry. The inside shape would coincide with the outside contour of the pipe, so that it could be left in position by the moulder until the bottom impression was almost completed.

The pattern-maker should supply filling-up pieces for the branches, which would be the same thickness as the frame, and provided with a guide which would make the guides for the main part of the pipe continuous. A batten over the top of each would enable them to be located in the frame, and a screw at each end would secure them. The branch guides on the frame need to be removed temporarily and replaced as required in the foundry.

Half-height sweeping boards should be prepared next, similar to those shown in Fig. 102. These are cut to the full outside diameter of the pipe, being checked to ride on top of the frame, but having the complete semi-circle projecting beyond the bottom, because the underside of the frame is on the centre. Wood about 1¾ in. thick would be used for these boards, and they require to be chamfered to ¼ in. at the sweeping edge. Where the pipe gradually reduces in diameter, a couple of making-up strickles would be made, as shown in Fig. 101.

Fig. 103 is the commonest type of loam board, and it is used when running up many kinds of horizontal cores on a spindle. Sometimes the pattern is made on the core, which necessitates the board being made to sweep the pattern diameters and then a thickness is screwed on the edge ; after the core is made, the strip is removed and the thickness is swept on for the pattern.

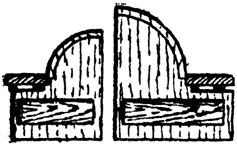


FIG. 101

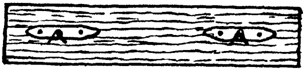


FIG. 103

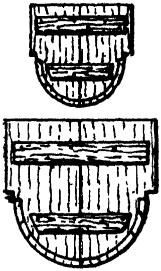


FIG. 102

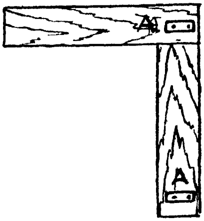


FIG. 104

Notches or nails in the edge indicate the length of core, while *AA* are diameter gauge strips for caliper setting. A plain circular core on a vertical instead of a horizontal spindle can be swept with a board like Fig. 104. Two stoppers are screwed to the upright, so that a gauge stick, fitting over the spindle, may be used. The ends of the gauge stick butt against the runner end of the stopper.

For cores of moderate size, and often for large ones, it is not left for the foundry to set the board. but a wood base plate and spindle are made at Fig. 105. The spindle is usually turned, the top being left square. A segment about $\frac{3}{4}$ in. or 1 in. is screwed to the plate. Sometimes a pin is turned on the top of the spindle, and the board revolves on this.

PATTERN PLATES

Patterns for large castings that are of a standard character can profitably be mounted on plates even when they are not moulded on machines, and small repetition work can be much more cheaply produced when mounted on pattern plates and machine-moulded. With the aid of pattern plates some moulds can be produced by hand almost as quickly as from a machine, and the castings are more accurate than those obtained from patterns without the use of plates.

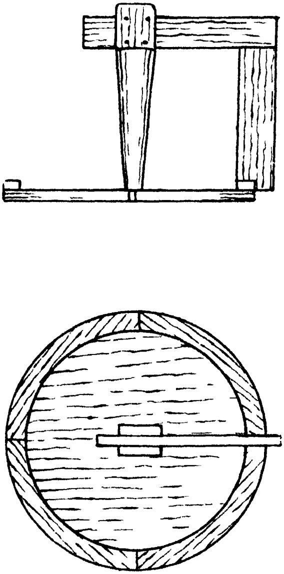


FIG. 105

A pattern plate consists of a plate slightly larger than the moulding-box with which it is to be used, and carrying pattern sections on one or both sides from which impressions can be taken to form a complete mould when the plate has been stripped. Holes are necessary through the plate to suit the pins on the moulding-boxes to be used. The joint the mould is required to have is formed on the plate, therefore, when sand has been rammed on it and stripped, no other toolwork is required in forming a joint. This applies also to runners, suitable shapes for which are secured to the plate, and the drag and cope can therefore be assembled without any tooling whatever.

Although there are many varied forms of pattern plates there are but two main types, the turnover plate and the reversible plate. The turnover plate carries pattern sections on each side of the plate, and it requires to be turned over to form the cope. While this type of plate is useful in jobbing foundries when hand moulding is resorted to, for machine moulding it is customary to prepare two plates, one for the drag and the other for the cope. These are used with separate machines, which avoids turning over the plate. The reversible plate carries the pattern sections on one side only, but they are so arranged that two impressions made will form a complete mould. In assembling the parts it is obviously necessary to reverse them. This type of plate is popular for work that is symmetrical, or when it is not important which side of a casting is made in the cope. Pattern plates may be of wood, metal, plaster, or a wax composition, any of which may be used for hand moulding. For power machine work neither plaster nor composition gives such good service as metal, or even wood.

Wood plates are frequently used for small work, and they are made to standard dimensions and have wrought iron dowel pins set in to suit the moulding-box pins. For flat-jointed work, however, standard machined cast iron plates are preferable. Pattern plates must be carefully lined off in order that the pattern may be set accurately upon them to form a correct junction when the drag and cope are fixed together for casting.

Metal plates are generally of iron, although aluminium is sometimes used, being considerably lighter and not subject to oxidization to such an extent as iron. Metal plates are more costly, being machined on each face and drilled accurately to suit the box pins. The thickness is variable, but should be as light as possible, consistent with strength, to ensure ease in handling. A common form, used for hand moulding, possesses handholes, as shown in Fig. 106.

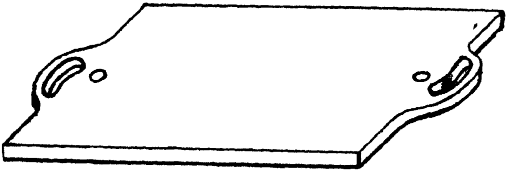


FIG. 106

The most common method of marking positions of patterns on wood plates is with scriber and trammels. A centre line passing through the centres of the pin holes should be accurately drawn. Pins may be set in the holes and a straight-edge used between the sides of each, when short lines can be drawn on the face of the plate, as shown in Fig. 107, between which the centre will lie. Dividers can then be used and the centre line scribed. Some prefer to use a straight-edge with the ends recessed half the diameter of the pins, as shown in Fig. 108, so that, when held in position from each side of the pin, marks made on the plate will coincide ; the centre can then be scribed between the two pin holes.

A jig is sometimes used for locating the centre line between the pin holes.

The method of locating pattern sections on a plate is shown in Fig. 109. Only one pattern is supplied jointed along the central plane, and the two parts can readily be located and fixed on a plate to form a reversible pattern plate. A pattern determining the shape of the runners can quickly be prepared, and fixed as shown. This form of plate is sometimes referred to as a double-sided pattern plate, but when the work is symmetrical and each box carries half the mould, only one side of the plate need actually be used.

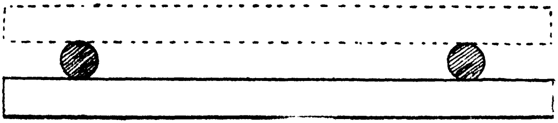


FIG. 107

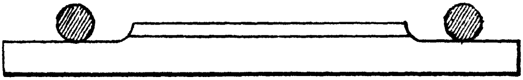


FIG. 108

Turnover plates or joint plates, with the patterns attached, may be made in a wax composition or in plaster of Paris for use by hand moulding, but it is better to make the patterns with the plate when these materials are used, because they are not so convenient for securing loose pattern sections. For use with plaster of Paris it is necessary to prepare a mould in plaster. A rough wood box large enough to take the drag pattern section will suffice, and it may be blocked out to reduce the space about the pattern into which the plaster is poured. The procedure is then as follows: Lay the pattern section flat on a board—it is better if the pattern and board are varnished—and apply a coating of sweet oil to all parts that are to be separated from the plaster; locate the roughly-made box and stop up any possible escape between the box and board. Pour just sufficient water into a container that will suffice for the drag, and sprinkle the plaster into it until both water and plaster are about level in the container. Stir up and pour into the box surrounding the pattern, using a stick to release any air that may be trapped. In about 20 min. it will be set sufficiently to allow it to be turned over, when the joint can be cut to requirements. It may be placed in an oven to hasten setting and drying, when the joint may be sandpapered in readiness for the cope part. Varnish the plaster joint if time permits, in order to prevent the oil being absorbed, as this will give a better parting. Repeat the procedure for the cope and make a hole through it for casting the pattern plate. Guides should be attached to the outsides of the box parts so that they will register again after being lifted. When the cope has set it may be lifted, the pattern sections withdrawn, and runners formed to be cast on the plate. Place the parts in an oven preparatory to varnishing the mould. It is

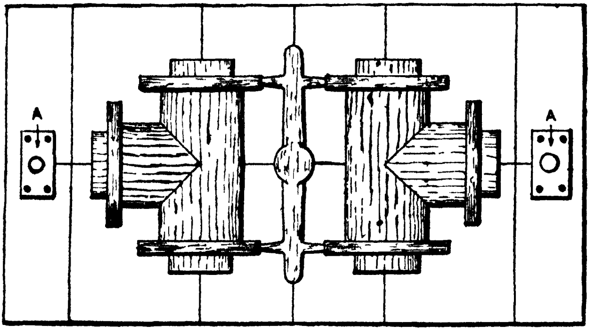


FIG. 109

necessary to prepare a frame to carry the plaster plate, making some arrangement about the inside so that the plaster will adhere. A suitable frame for this purpose is shown in Fig. 110, nails being knocked in about the inside edge around which the plaster will flow. If this frame is located on the drag, and the cope is set over in its correct relation to the drag, the plate can be cast.

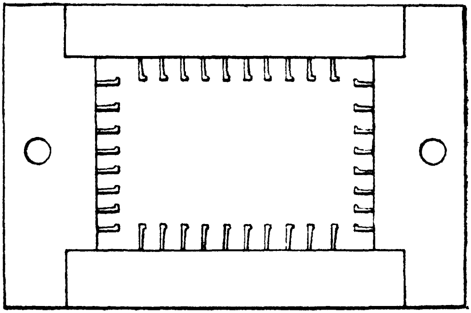


FIG. 110

It is necessary to apply oil to the mould and joint, going over them carefully with a soft brush. The resulting pattern plate, when dried and cleaned with sandpaper and varnished, will give excellent results when hand-moulding is resorted to. Such a plate is not suitable for power-moulding machines of the jar-ramming type, because the plaster does not stand up to the jarring action for very long.

On the reversible form of plate the patterns are carried on one side only from which both impressions are made. As the shapes for both drag and cope are required on one side, it is necessary to prepare the moulds from the master patterns in such a way that they can be placed together to form the drag of the plate mould, or partitioned so that each can be cast separately. The former method is suitable for a solid cast plate, and special boxes are necessary. A suitable box is one in which the drag is prepared in two equal parts and flanged at the joint for bolting or clamping together. The joint requires to be machined. Besides the pins and pin holes for registering the box parts, the drag carries separate pin holes for introducing loose pins. With this form of box the drag is in the first place separated, and a blank side is secured to each part. These then form the two parts for a separate box, as shown in Fig. 111, in which the mould can be made. Room is required about the sides to enclose properly the size of plate with which the patterns are required to be cast. When the mould has been completed the blank ends are removed and the two parts again secured to form the drag for the plate mould, then the thickness of plate is made up. A flat cope is prepared on a ramming board to cover the drag.

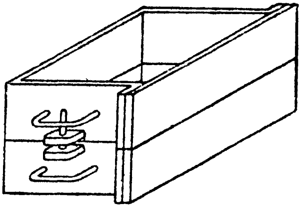


FIG. 111

GEARING

Theoretically, when two cylinders having their axes parallel roll on each other, they transmit motion by frictional contact, but a uniform rolling motion is not transmitted with regularity. Slip occurs, and to overcome this, the peripheries of the cylinders have teeth so shaped that a uniform rolling motion is maintained. The peripheries of the two cylindrical bodies become the pitch circles of the gears on, or from, which the sizes of teeth and diameters of gear are measured. That part of the tooth outside the pitch circle is known as the addendum, point, or face, while that within the pitch circle is known as the dedendum, root, or flank of the tooth. The circular pitch represents the length of arc between the centres of adjacent teeth measured on the pitch circle.

Rules. When the diameter of the pitch circle and number of teeth are given, to obtain the circular pitch, multiply the diameter of the pitch circle by 3·1416, and divide by the number of teeth.

When the number of teeth and the circular pitch are given, to obtain the diameter of the pitch circle, multiply the number of teeth by the circular pitch and divide by 3·1416.

When the diameter of the pitch circle and the circular pitch are given, to obtain the number of teeth multiply the diameter of the pitch circle by 3·1416 and divide by the circular pitch.

For cut gears the diametral pitch is frequently given, which is the number of teeth per inch of the pitch circle diameter. To find the circular pitch divide 3·1416 by the diametral pitch.

The two designs of teeth, almost universally used because they have theoretically correct forms for transmitting a uniform rolling motion, are the cycloidal and the involute curved teeth. A cycloidal curve is traced by a fixed point on the periphery of a cylindrical disc when the disc is rolled on a straight edge. If the disc is rolled on the outside of a circle representing, say, the pitch circle of a gear, then the curve generated is an epicycloid, and when rolled on the inside of a circle the curve formed is a hypocycloid. If this diameter of the disc is equal to one-half the diameter of the circle upon which it rolls, then the hypocycloidal curve will be a straight line passing through the centre.

The involute curve is the curve that would be drawn by a tracer at the end of a thin band which will not stretch, and is drawn tight while being unwound from a cylindrical body.

In principle, cycloidal teeth are double curved teeth, while involute teeth are single curved, though there are modifications of the latter involving two curves. In the cycloidal system, the teeth on a rack are formed with two similar curves, whereas in the involute system the sides of the teeth are straight and, generally, at an angle of 75 degrees. Of the two types the involute is usually preferred when the teeth are to be machine cut, because fewer cutters are involved than when cutting double curved teeth, but for cast gears either form may be used in one set of gears.

In drawing a cycloidal curved tooth the disc that has been referred to is known as the generating circle because its diameter is generally one-half that of the pitch-circle diameter of the smallest pinion in the train of gears.

For all practical purposes the use of an odontograph, designed by Professor Willis, meets all requirements in the development of cycloidal teeth, but it is advisable for the pattern-maker to be familiar with the geometrical method of setting out the curves, so that, failing the use of an odontograph, he will be able to define the form of tooth required.

In setting out the tooth curve geometrically, the pitch circle, addendum circle, and the dedendum circle should be first drawn. The pitch circle is then divided to correspond with the number of teeth desired. In order to set out the tooth curves from the point *A* on the pitch circle, equidistant points should be set out on each side of it and on the pitch circle, as shown in Fig. 112. Through these points radial lines are drawn and, from centres upon them arcs are drawn representing the arcs of the generating circle.

In order to determine the points of the tooth curves it is necessary to measure off, on these arcs of the generating circle, distances corresponding to the portion of the pitch circle that has been rolled over between the point *A* and the point where the radial line intersects the pitch circle. For instance, the length of arc *G A* measured on the pitch circle from *G* gives the point *N*. Point *O* is determined in a similar manner.

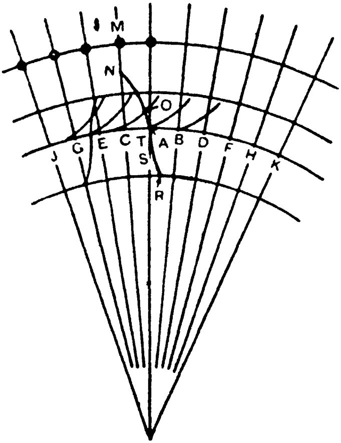


FIG. 112

A curve drawn through the points *N*, *O*, *A* is part of the epicycloidal curve and is the curve which forms the face of the tooth. By using the same method to determine the points *T*, *S*, *R*, through which the hypocycloidal curve passes, the root curve can be formed. Once these curves have been drawn it is an easy matter to find radii that will define a true curve very near to the developed curve which will facilitate the marking of all the teeth.

To draw an involute curve geometrically for a tooth it is necessary to draw a base circle, as it is from this circle that the involute curve is drawn. This base circle is always inside the pitch circle by an amount varying with the diameter of the gear and also with the degree of obliquity of the tooth. The tooth may be of 15 degrees or 20 degrees obliquity, but usually the former.

In drawing the involute curve for a 15 degrees tooth, the pitch circle is first drawn, then through a point *A*

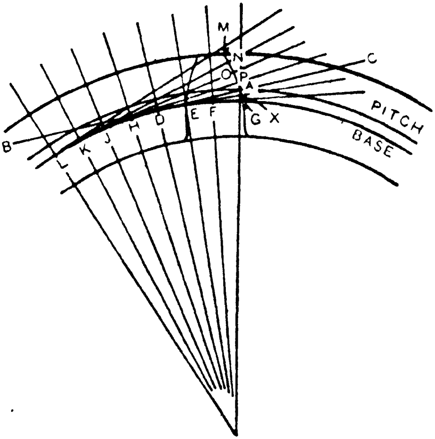
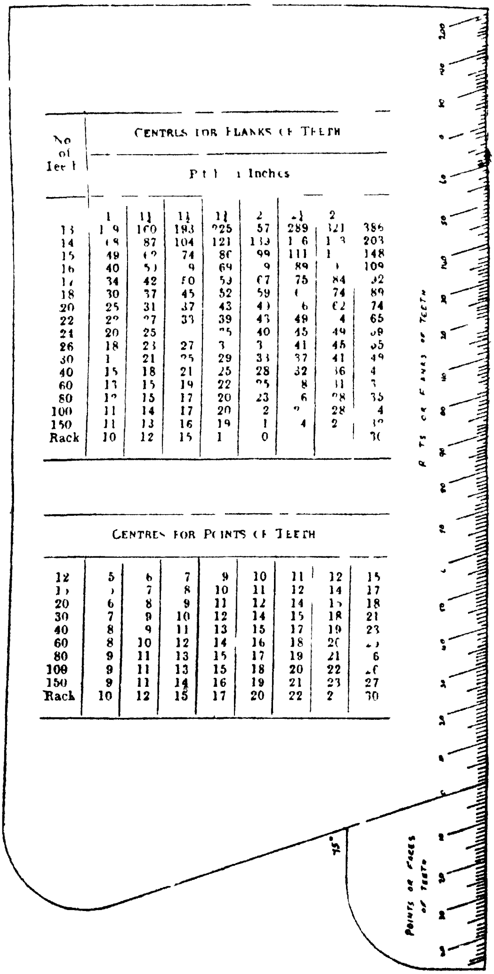


FIG. 113

on the pitch circle, Fig. 113, a line *BAC* is drawn at an angle of 15 degrees to a tangential line from *A* with the pitch circle. The base circle is then drawn at a tangent to *BAC*. Any convenient number of equidistant points are set out from *X* on the base circle to the point *D*, from which *BAC* is tangential, and the same distances are set off on the base circle. Tangents are drawn from each point, as in Fig. 113, and, along the tangential lines, distances corresponding to the length of arc to the point *G* are marked; thus *LM* is equal to length of arc *LG*, *K N* is equal to *KG*, *JO* is equal to *JG*, etc., giving the points *M*, *N*, *O*, *P*, through which a curve can be drawn which is the involute curve. Once this has been developed it is convenient to find the nearest radius that will, for practical purposes, give the curve, when the circular pitch can be set out and the teeth formed. When the pattern-maker is familiar with these methods he can always revert to first principles and develop a suitable curve for teeth if other facilities are not available.

The odontograph or scale for setting out cycloidal curved teeth is shown in Fig. 114. It may be marked out on stiff paper, wood, celluloid, or aluminium. The divisions along one edge and from each side of zero are each ½ in. apart, and these are subdivided into ten parts. The method of its use is shown in Fig. 115, with which some explanation is necessary. Supposing a pinion is required having 22 teeth and 1 in. circular pitch. The pitch circle is first set out and the point *A* determined. Half of the circular pitch is set out at *B* and *C* on each side of the point *A* on the pitch circle, and lines drawn through the centre of the pinions from these points *B* and *C*. By referring to the scale a number is given for the flank curve; under column 1 in. and alongside 22 teeth, the number 22 is given. If the scale be located with its zero point coinciding with *C* on the pitch circle, and the angle of the scale coinciding with the line passing through the centre of the pinion, the 22 points can be read from the scale and the point *D* indicated; with the compass point at *D*, and radius *D A*, the flank or root curve can be drawn. Again referring to the scale, it is found that 6 is the nearest to provide the centre for the point curve. The scale is set so that zero coincides with *B* and the pitch circle; note the 6 divisions at *E*. With *E* as centre and *E A* as radius, the point curve is described. Once the radii have been obtained, and the centres of the



No of Teeth	Centres for Flanks of Teeth							
	Pitch in Inches							
	1	1¼	1½	1¾	2	2¼	2	
13	1 9	160	193	225	57	289	321	386
14	68	87	104	121	133	1 6	1 3	203
15	49	62	74	86	99	111	1	148
16	40	50	9	69	9	89	[illegible]	109
17	34	42	50	59	67	75	84	92
18	30	37	45	52	59	6	74	89
20	25	31	37	43	49	6	62	74
22	22	27	33	39	43	49	4	65
24	20	25		35	40	45	49	59
26	18	23	27	3	3	41	45	55
30	1	21	25	29	33	37	41	49
40	15	18	21	25	28	32	36	4
60	13	15	19	22	25	8	11	3
80	12	15	17	20	23	6	28	35
100	11	14	17	20	2	[illegible]	28	4
150	11	13	16	19	1	4	2	32
Rack	10	12	15	1	0			30

Centres for Points of Teeth

12	5	6	7	9	10	11	12	15
15	5	7	8	10	11	12	14	17
20	6	8	9	11	12	14	15	18
30	7	9	10	12	14	15	18	21
40	8	9	11	13	15	17	19	23
60	8	10	12	14	16	18	20	25
80	9	11	13	15	17	19	21	6
100	9	11	13	15	18	20	22	26
150	9	11	14	16	19	21	23	27
Rack	10	12	15	17	20	22	2	30

Fig 114

curves located, it is only necessary to describe circles from the centre of the pinion, one passing through *D*, upon which all centres for root curves will be located, the other passing through *E*, upon which all centres for point curves will be located, when the teeth have been pitched off.

Pinions and spur wheels are the more common forms for which patterns are made, and their construction varies slightly, according to the design. With the majority, segmental construction is adopted in order to maintain a continuous grain. This method is frequently used for the pinions, even though no lightening-out is effected, especially if many castings are required. For small pinions, where the width of face is 2 in. or upwards, the use of solid timber, with the grain in the direction of the teeth, facilitates the production of the pattern, providing no lightening-out is necessary.

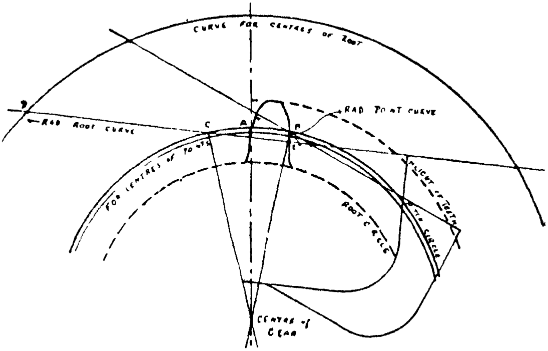


FIG. 115

For slightly larger wheels, in which the rim and bosses are made up on a plate, the plate as well as the rim is built segmentally, usually in two thicknesses; and, while a good taper should be given to the inside of the rim and also the bosses on each side of the plate, the stripping of the cover is facilitated when the top boss is jointed. Its position should be located by a spigot and socket joint.

With regard to the making of the teeth for either pinions or spur wheels many methods may be used, according to the quality and degree of accuracy required. For standard work three methods predominate, and are illustrated in Fig. 116. *A* represents the method of dovetailing each tooth. Another method, illustrated at *B* in Fig. 116, consists in preparing and fitting blocks and securing them by glue and panel pins direct to the rim, spacing them to correspond with the required circular pitch. This is the most economical method. The third method, illustrated at *C* in Fig. 116, is a variation of the latter method and is used advantageously to obtain a small fillet at the root of the tooth. In this instance the rim is turned to a diameter less than the root diameter and the blocks are made wider, so that they butt joint each other.

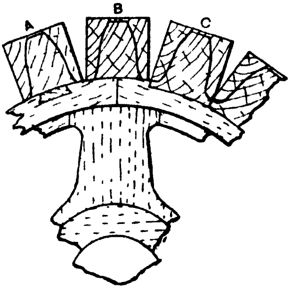


FIG. 116

Much of the labour involved in making teeth can be reduced by making a jig in which teeth of the required shape and size can be made without individual marking out; such a jig is illustrated in Fig. 117. It consists of a block, preferably of hard wood, one side of which is shaped to the required form of the tooth and the other side cut to form a dovetail. About the centre of the tooth shape a recess is cut, corresponding exactly with the length and depth of a tooth. Two pins are driven into the bottom of the recess, and parts left projecting are sharpened with a file and a hole is bored through the centre to admit a screw. A separate piece of wood is fitted over the dovetail and at right angles to the jig for holding in the vice. A number of blocks are prepared for the teeth, shaped to fit on the rim, and cut to the correct length, and these are fixed in the jig and shaped off to follow the contour of the latter. The same degree of accuracy cannot be obtained with this as with other methods, but if care is exercised in spacing the teeth, it should be relatively accurate.

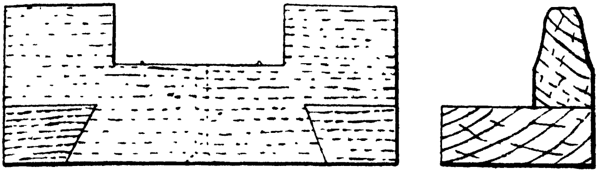


FIG. 117

PATTERN SHOP MACHINES

Unless wood-working machines are in excellent condition they are inaccurate and leave so rough a surface on the timber that a great deal of hand finishing is necessary. It should not be necessary for the pattern-maker to plane wood that has been over or through a planing machine, nor to cut half-laps that have been cut at the circular saw. There is no reason why timber worked at a machine should not be as well finished as timber worked at the bench.

There is so much dust, and especially sawdust, in the pattern shop that the lathes, and indeed all the machines, get out of truth unless they are kept clean. The machines should be oiled first thing in the morning and it is better that this should be done before the machinery is started. It is not possible to clean them thoroughly every day, but it should be done at least once a week. The lathes are usually the most neglected machines. If the caps are left off the oil cups, they soon fill with dust, which gets into the journals and grinds, the consequence being that it is not possible to turn work true. Wood-turning lathes run at such high speeds that they are more liable to heat than metal lathes, but the greatest damage is done to lathes, especially the smaller lathes, by hammering on the centres and the faceplate. It is much easier and better to tap the centre on the ends of the job before it is put into the lathe at all. It is an equally simple matter before screwing on the chuck to cut a washer from sandpaper and put it behind the chuck. If this is done it will always unscrew. Far better than hammering the chuck is the method of heating the screw with a gas flame. This expands the chuck sufficiently to loosen it.

The work for both the circular saw and band saw in the pattern shop is comparatively light and the saws should be kept in good condition. It is a very easy matter to twist a circular saw and almost as easy to put it right, unless the saw has been twisted by heat. The packing should press close on the saw, and if a piece of wood is pressed against the saw and held steady the saw will again run true. It is a great mistake to rip a board for half its length and then reverse it. It ought to be pushed right through. Reversing the timber not only damages the saw but it invariably loosens the packing. It is wise to have a small shelf in front of the saw-table for a forked stick with which to push the wood.

Band saws are often changed when they are not really blunt but dirty, and they should be cleaned with paraffin without being taken off. A well-kept band saw is the most valuable in the pattern shop. There is much difference of opinion as to the correct tension of the saw. A slack saw is not so easily broken, but it cannot be relied upon to take a deep square cut. There is nothing more annoying than to have a piece of work undercut at the saw through its being too slack or the block in the table not guiding it properly. Saws last longer if the rubber on the wheels is kept clean and free from sawdust.

The most sensitive machine is the planer. A grain of sand on the wood reduces its usefulness, and the only way of obviating this risk is to cut off the dirty ends of the timber before it is planed. The surface of the timber should be well scrubbed with a wire brush to remove any dirt. The precaution of sawing dirty ends is also necessary before finishing off at the trimmer.

Nearly all pattern shops have a sand-papering disc and rollers. These are great labour savers and one sheet of paper will keep a shop of fifty men going for a week. The paper is spoilt by grinding end grain on it and consequently burning it.

THE LATHE

A very considerable proportion of pattern-making is executed at the lathe. Wood turning differs from metal turning in that the turning tools are held by the workman's hand, and it is very seldom that a slide rest is used. The lathes in pattern shops are often adapted metal-turning lathes, although more satisfactory work can be done in machines that have been designed specially for turning wood.

With medium-sized and large work it is usually safer and more satisfactory to rough-down on a comparatively slow speed and finish on a faster speed, but with delicately-built work it is sometimes advisable to begin and finish on a fast speed ; it depends largely on the manner in which the work is balanced in the lathe. Centrifugal force has to be considered when turning, and, if the work is unbalanced, it is desirable to rough-down on a lower speed to obtain balance ; otherwise the vibration may be such as to cause the job to fly out. It is this vibration that frequently determines the speed. It is much easier and safer to turn work of small diameter at a very high speed. It is almost, though not quite, true to say that large work (work, that is to say, of 5 or 6 ft. diameter) cannot be turned too slowly.

The " T " rest is the most useful rest for the pattern-making lathe. In addition to rests, both large and small lathes have fork and cone centres. The forked chuck is sometimes called a " swallow-tail " and sometimes a " butterfly." The forked centre is the driving centre, and the shank which enters the lathe spindle is tapered, making a frictional contact with the spindle only. These centres are quite satisfactory for small work, especially if it is not in halves, when it will probably be necessary to remove the work from the lathe to fit flanges. However, it is necessary to use either hardwood or iron centre plates to ensure that, when the work is replaced in the lathe, it will run true. To save time, pattern-makers sometimes take a risk and do not use plates for such work.

Hardwood centres are satisfactory for work that is not more than about 6 in. diameter. According to the diameter, the hardwood face plate should not be less than ½ in. thick, and need not be more than 1 in.

Iron face plates screwed on to the mandrel of the headstock are used for all work that is best turned without the aid of the cone centre. It is seldom that pattern-work is screwed directly on to the iron face plate, perhaps the chief reason for this being the probability of the workman's tool touching the iron. A wooden face plate or chuck is invariably screwed to the iron face plate and turned. For large barrel work the forked centre is not sufficient, and the screwed face plate is frequently used together with the cone centre, but the end of the barrel carrying the face plate needs to be square; otherwise there is difficulty in securing alignment. Because of this difficulty it is better to use two centres in the lathe, and a plate is usually screwed to the end of the barrel, which has a pin riveted to it, and this pin slips into a hole in the ordinary face plate, which carries a cone centre. Another plate is secured to the other end of the barrel, and both these plates are countersunk to take the cone centres. The action is similar to that adopted when turning between centres in a metal turning lathe; thus, when the lathe is started, the job, which swings on the two centres, is driven by the face plate driving the pin. These iron centre plates are usually made about ½ in. thick and of 6 in. diameter or more.

While with segmental work it is advisable to leave ⅜ in. diameter for turning and about ⅛ in. on faces, it is not necessary to build a barrel more than about ⅛ in. above the finished diameter. A great deal of timber is wasted in turning, and the waste can be reduced with careful building and centring. Small cylindrical bodies should be got out ¼ in. or ⅜ in. larger than the finished diameter. If a pattern is in halves, it is advisable, in addition to centring plates, to insert screws at both ends, and this does not necessitate leaving much extra length. For solid work, 2 in. greater than the pattern length is usually sufficient, and, when in halves, about 3 in. This allowance serves to clear the work and also to clear end screws. Small cylinders should never be turned from square. It is a simple matter to plane or saw the corners, making a rough octagonal block.

When turning large barrels, in addition to iron centre plates, it may be necessary, if the plates are not of large diameter compared with the diameter of the work, to screw additional battens on the ends, or sometimes dogs may serve the purpose.

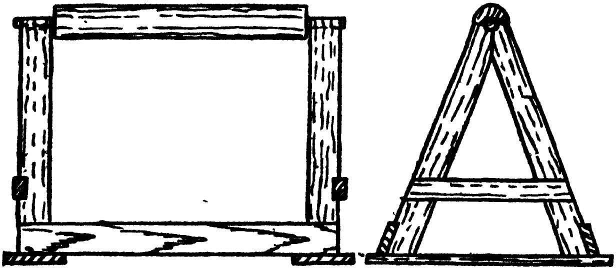
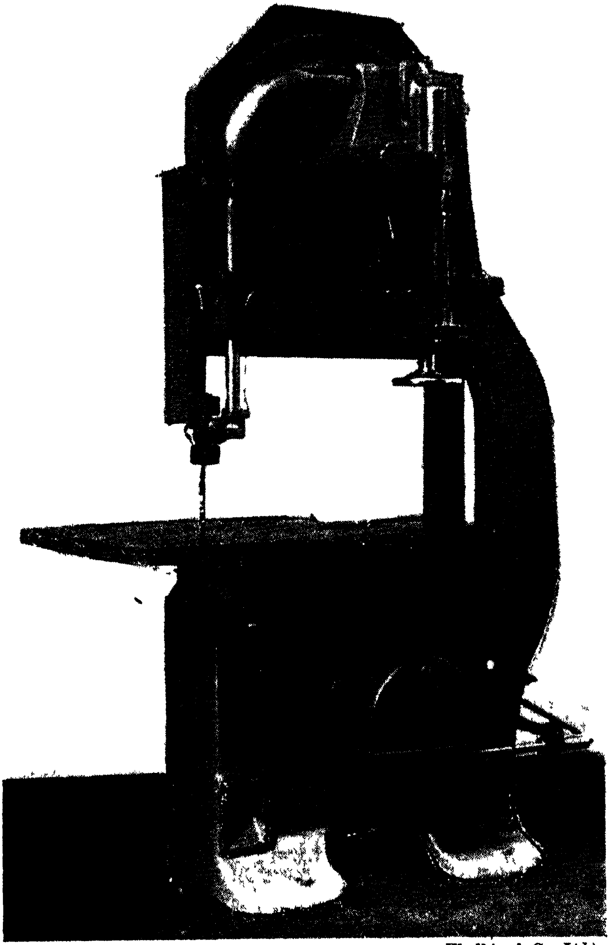


Fig. 118

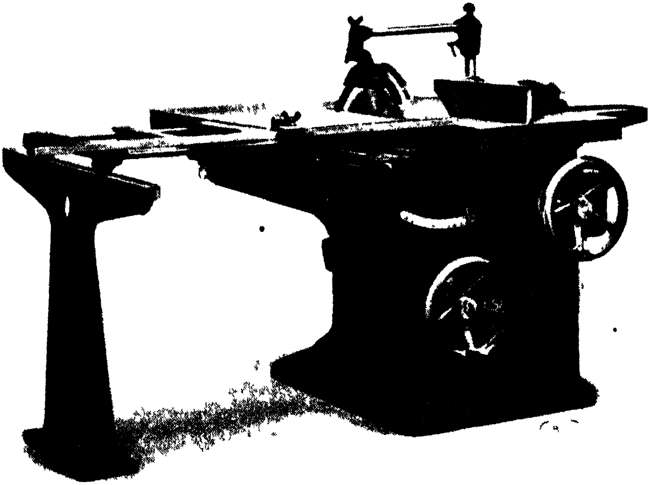
SAWS

The band and circular saws are next in importance to the lathes, and the band saw is the more useful machine saw. A jig saw is installed in some shops, but it has a very limited sphere of usefulness. If much heavy work has to be band sawn, roller trestles similar to Fig. 118 should be used; two or three such supports, having the top of the roller level with the surface of the saw table, maintain the horizontal position of the timber to be cut and the rollers are of great assistance when following a curve. The usefulness of either



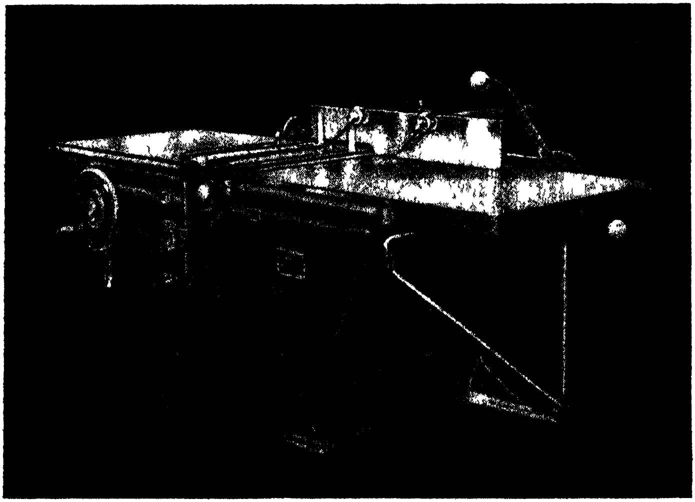
(*Wadkin & Co. Ltd*)

FIG. 119. MODERN ELECTRIC-DRIVEN BAND SAW



(*J. Sagar & Co , Ltd*)

FIG. 120. DIMENSION SAW WITH ADJUSTABLE TABLE



(*Thos White & Sons, Ltd*)

FIG. 121. COMBINATION PLANER

circular or band saws is in proportion to the condition in which they are kept.

Wet timber requires a saw with more set than dry timber. What actually happens is that the fibre of the wood springs back after the teeth of the saw have cut it. Setting a saw is so bending the alternate teeth to different sides that, as the saw progresses through the timber, the blade behind the teeth has sufficient clearance. This set can be given by means of a punch, but better results are obtained with a tool called a saw set, which can be adjusted to give any set necessary.

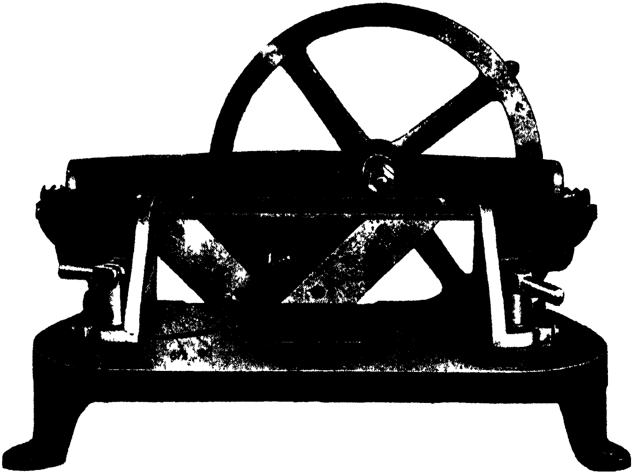
When circular or band saws require sharpening it is first necessary to reduce all the teeth to the same length. Were this not done, the strain on the saw would be unequal, and some teeth would be doing all the work. It is impossible to obtain a clean cut with a saw that is badly set or sharpened. With regard to sharpening, there is no definite angle for filing the teeth. An experienced man will wedge a circular saw in the saw bench and sharpen it so that all the teeth will be of uniform angle, but, on the other hand, nothing is easier than to get all the teeth at different angles. It is, to a great extent, a matter of experience and care.

When filing rip saws, the cutting edge should be filed so as to be square across the face of the tooth, while for cross-cut saws, the bevel of the edge should taper to square, about half way of the length of the tooth. The fillet at the base of the teeth is called the " gullet," and this should always be kept round.

SAND-PAPERING MACHINES

The most useful sand-papering machines for pattern-making are the disc and rotary machines. The double disc sand-papering machine is installed in many pattern shops, and with the machine are useful attachments. This machine obviates the paring of external curves with chisels, and, for internal curves, rotary sanders are used.

On a wood grinder of the disc type angular, square, and outside circular grinding can be very quickly executed. The abrasive is secured by a wire rope at the edge of the disc and the use of glue and a press is eliminated. A fence enables duplicate pieces to be sanded to size and it is moved to and from the disc by means of a lever. This fence swivels for angular work.



J. W. & C J. Phillips, Ltd)

FIG. 122. TYPICAL WOOD-TRIMMING MACHINE

The rotary or oscillating bob grinder is exceedingly useful for internal curves. The sander most generally used in the pattern shop is the combined disc and rotary machine. The maximum degree of usefulness of sanders or grinders can be attained only by men with experience and integrity.

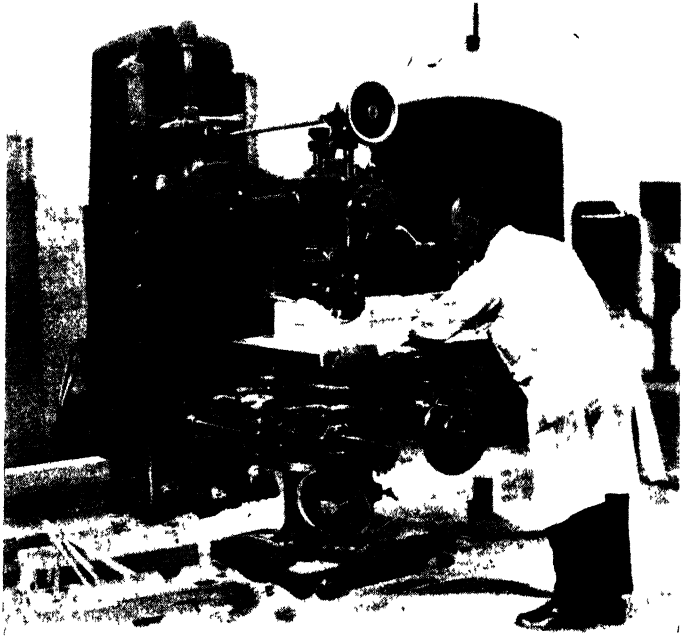
To prevent accidents it is essential that these discs should be adequately guarded, but for special work requiring almost the full height of the sander, the guard can be removed to give the worker better facilities for following the line, and as the controlling influence over the work should be in the hands of one person, tallow ought to be applied to the surface of the table when the work is heavy and awkward, in order to reduce friction.

TRIMMERS

Trimming machines are almost essential in modern pattern shops. The trimming machine knives must be sharp to do good work. The most important use of the trimmer is when building segments. If a trimming machine is in good condition, it makes a perfect finish, and it should never be necessary to plane edges after being trimmed. If, in the case of segments, the templet is made to the finished size, not more than $\frac{1}{16}$ in. should be left at the band saw for finishing. It is sometimes an advantage to clamp a piece of thin timber to the machine table against which the segments can be pressed when cutting. The exact outline of this guide piece can be obtained by placing the thin timber on the table against the fence or wing guide and laying the templet on top of it, the finished edge being set against the machine knife. Such a guide ensures that the edges are accurately radial.

WOOD MILLERS AND OTHER MACHINES

In all pattern shops there must be a grindstone, and there ought to be a set of grinding wheels for gouges and a boring machine. An almost indispensable machine also is the planer, either for surfacing or thicknessing timber. The wood miller is an exceptionally valuable machine in the hands of a skilled operator. The wood miller can be used for finishing much work that would otherwise be turned, for forming half-laps, and for cutting out core-boxes. While pattern-makers use all other machines, the wood miller must only be used by one man, and its value would appear to be limited only by his ingenuity.



(*Wadkin & Co Ltd*)

FIG. 123. THE WADKIN UNIVERSAL WOODWORKER

The miller is invaluable for core-box work and also for a large variety of shaping sections of patterns. There is still a certain amount of cast gear work, and cutting the teeth of gear patterns is one of the most costly and intricate operations in the pattern shop. The cutting of spur and bevel gears and of worm, helical, and spiral gears is one of the ingenious developments of the miller. Practically any diameter or pitch may be cut and no marking out beyond one tooth is necessary. For both spur and bevel gears a plain dividing head only is required.

For worm, helical, and spiral gears there is a gear-cutting fixture which carries a dividing head. This is coupled to the lead-screw of the table traverse and practically any desired spiral can be cut. Indexing is the same as applied to metal cutting practice.

SECTION VI

IRON AND STEEL FOUNDING

BY

J. McLACHLAN

AND

CHAS. A. OTTO

SECTION VI

IRON AND STEEL FOUNDING

INTRODUCTION

THE production of iron and steel castings that are sound and reliable is full of difficulties. So many causes operate against soundness that the founder must possess experience and skill of a very high order to produce castings that fulfil modern requirements. The most prominent of the difficulties that operate against soundness are due to contraction ; particularly is this the case with steel castings. Conflicting forces in a casting that are due either to change in form or changes in sectional thicknesses produce stresses which may seriously impair the strength of the casting, or even cause fracture. Shrinkage of the fluid metal may cause cavities or may cause parts of the casting to be porous in texture. reducing its capacity to withstand high pressures. Blowholes may be the cause of weakness, or the presence of scabs on a casting may seriously affect its soundness. The raised scab on a casting can easily be removed, but it is frequently caused by the dislodgment of part of the mould, and this is usually trapped in such a position in the mould that it is fatal to the casting. The dumb scab, which is a depression in a casting, is a source of weakness itself.

The introduction of nails, studs, chaplets, and the use even of chills may seriously interfere with the soundness of castings, and dull metal or its unsuitable composition may reduce their reliability. A shortage of runners to accommodate the intricate design of a casting will cause either a short run or cold shut, which prevents parts uniting properly. These are but a few of the difficulties which the founder must overcome, and the success that attends his efforts is demonstrated by the soundness of the castings he produces.

In no other industry do the conditions needed to ensure reliability in the product vary to such an extent as in founding. Each metal and alloy from which castings are produced has its own peculiarities, and particular difficulties are encountered to a varying extent, and not least in the making of iron and steel castings.

Broadly speaking, the work in the foundry involves the melting of metals and alloys, the preparation of moulds, and the casting or founding of metal. The kind and quality of the metal to be melted and the amount required introduce variations in furnace plant, and the size and intricacy of the work to be done necessitate variations in mould construction with a view to economical production combined with safety in the casting of the metal.

MELTING EQUIPMENT AND APPLIANCES

Melting furnaces are of first importance in the foundry, and in the iron foundry the cupola, the simplest and perhaps the oldest of furnaces, is still the most economical and, with the exception of the electric furnace, the most efficient. The most common cupola design consists of a mild steel shell of considerable height having an air belt surrounding it near to the bottom and lined inside with firebricks and ganister. Connecting the air belt with the inside of the furnace are a number of tuyères. Just beneath the tuyères and at any suitable position about the cylinder shell, an outlet is made for slag. At the bottom is a large "D"-shaped aperture known as the breast hole, used for firing the cupola and for making up the hearth preparatory to starting. On the other side and a little above the bottom plate, to allow for the hearth, is the tapping hole. At a considerable distance above the bottom plate, the amount varying with the inside diameter of the cupola, is another large " D "-shaped aperture known as the charging hole. Usually a platform surrounds the furnace stack just below the bottom of the charging hole.

There are three types of cupolas in use to-day—the solid-bottom, the drop-bottom, and the receiver types. The solid-bottom type is the oldest type, and many foundrymen consider it safest for long blows, but this is largely due to prejudice. Gradually the more modern drop-bottom furnace is being installed because it is cleaner and more convenient in practice. A solid-bottom furnace is drawn through the breast hole after a " blow," and the residue cooled, making a very disagreeable job for the furnaceman. The drop-bottom type enables the residue to fall into a bogie, by which it can be transferred to a special tip for cooling and recovery. The hearth in a solid-bottom furnace is more or less permanent, being generally made up with ganister or some highly refractory material; on this account it is presumed to be safer than the drop-bottom type, for which ordinary floor sand is usually employed to make up the hearth. The latter type, however, offers better facilities for repairs, and with reasonable care in the preparation of the hearth there is little likelihood of a run out.

The receiver type of cupola, Fig. 1, is invariably associated with the drop-bottom type, but it has attached, as part of the structure, a receiver into which the fluid metal runs directly it reaches the hearth of the furnace. The advantages derived from this addition are the regularity of the quality of metal obtained. The receiver becomes a mixer, and since it is in contact with the furnace at the top as well as the bottom, there is little loss of heat from radiation once the receiver has become thoroughly heated. The metal is tapped from the receiver as required. Extra time is involved

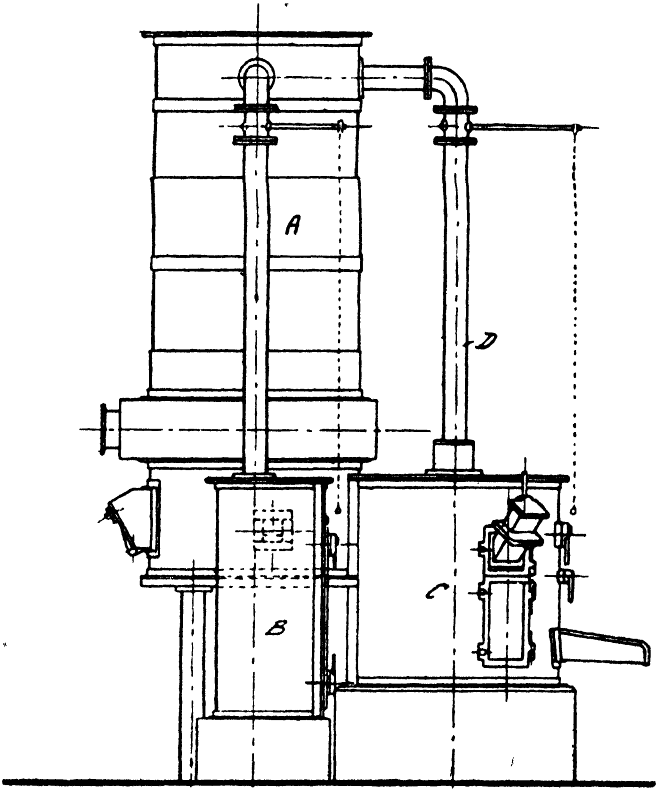


FIG. 1. PATENT "REIN" STANDARD CUPOLA

A = Furnace Shaft
B = Slag Collector
C = Receiver
D = Receiver Heating Equipment

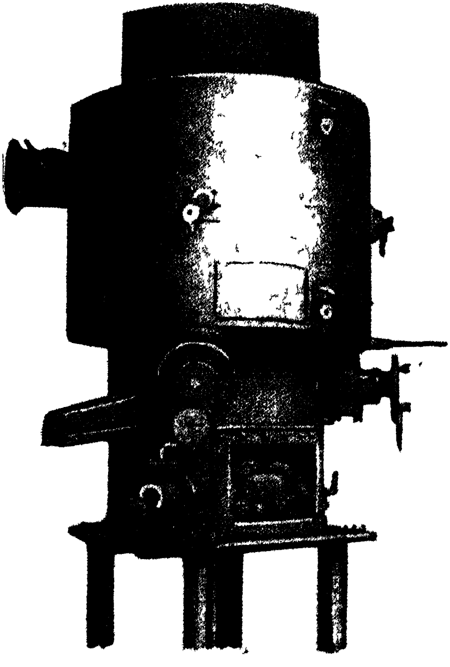
in drawing, and the tap hole between the furnace and receiver must be kept open.

Cupolas without receivers collect the fluid metal on the hearth, from which it is tapped at intervals into ladles. Generally, large ladles act as receivers, many tappings being necessary before they contain the quantity of metal required. In some instances cupolas are left open from the first signs of metal appearing until the end of the " blow," a receiver being used from which metal is transferred to carrying ladles.

The efficiency of a cupola depends in a large measure on the tuyères and the volume of air forced through them. The air introduced should be distributed as evenly as possible over the area of the cupola, in order to obtain a regular consumption of fuel. To consume 1 lb. of coke 134 cub. ft. of air is necessary, or, if the ratio of melting is, say, 7 to 1, that is, 7 lb. of metal to 1 lb. of coke, the amount of air per pound of metal will be approximately 19 cub. ft., and this multiplied by 2,240 will give the amount of air necessary to melt a ton of metal. The latter method of calculating is the usual one adopted, although really it depends upon the amount of coke to be consumed. The ratio of metal to coke is a variable one, thus the air required per ton of metal to be melted will be variable.

While the cupola is more convenient and more economical for general work in the iron foundry, the reverberatory or air furnace possesses advantages under certain conditions. The metal is stronger and not contaminated by the fuel as in the cupola. Draught is usually induced by a long flue, and the fuel does not come into contact with the charge. It is a low-efficiency furnace as compared with the cupola, the ratio of metal melted to fuel consumed being much lower. Although not in general use in iron foundries, reverberatory furnaces are frequently used for producing special forms of chilled castings and for malleable castings.

Much scientific attention has been given to cupola design and practice in recent years, with a view to increasing heat efficiency, and it has been discovered that by controlling the volume of air to approach more nearly the theoretical quantity required to consume completely the carbon in the coke, a greater efficiency is secured. In order to obtain a closer relationship of the amount of air entering the cupola in a given time, the late Mr. T. C. Fletcher, as consultant to the British Cast Iron Research Association, developed a cupola design in which facilities are provided for controlling the amount of air passing through the tuyères (Fig. 2). In addition to the main tuyères smaller auxiliary tuyères are placed above them, the object of which is to give an additional supply of air to facilitate the combustion of carbon monoxide formed just above the lower tuyères. Fine adjustable screw valves enable the size of the blast inlet of the main tuyères to be altered



(*The Constructional Eng Co Ltd*)

FIG. 2. THE BALANCED BLAST CUPOLA DEVELOPED BY THE BRITISH CAST IRON RESEARCH ASSOCIATION

to suit requirements. Although the air passes through the valves at high velocity the tuyères are so designed that a soft blast is produced. This balanced-blast design of cupola is being applied for malleable cast iron as well as grey iron with complete success, and a great number are now in operation. Its main advantages are reduced coke consumption, and high temperature metal comparatively free from oxidization.

Rotary furnaces of the Brackelsberg, Sesci, or Stein types are particularly suitable for melting large quantities of special grey iron, malleable iron, or even steel for castings. The two former are fired by pulverized fuel and involve pulverizing and storage plant, while the latter is oil fired. These furnaces are capable of utilizing relatively low-priced scrap and the melting losses are low; the carbon contents of the iron can be controlled, which facilitates the production of high-duty cast irons. These furnaces approach more nearly to the cupola as economic melting units.

The use of the electric furnace for producing high-quality cast iron is the more modern appliance for coping with the demand for special castings of a reliable character. The need of castings that can withstand repeated shocks in addition to high temperature, has focused attention on the possibilities of the electric furnace. This type of furnace is now being employed to a limited extent for superheating the metal after having first melted it in a cupola, the arc furnace being almost invariably used.

For special compositions, when the cost of melting is of minor importance, the indirect arc furnace is used to some extent. A furnace of this type is the Birlec-Detroit rocking furnace, in which very close control can be maintained over metal composition. The melting losses are practically negligible and the molten metal can be held in the furnace for any length of time. The furnace may be used for melting cold charges, or molten metal from the cupola may be charged for superheating or for the production of alloy cast irons.

There are four different types of furnaces used in the steel foundry—crucible furnace, electric furnace, converter, open hearth furnace—and it would be extremely unwise to state without qualification that one particular type is superior to all others. Production costs and quantities have to be considered as well as quality. In point of quality crucible steel takes first place, closely followed by electric steel, but in small foundries preference is given to the converter process for economical reasons, while the open hearth furnace, because of its larger capacity, is more economical for large steel castings.

Crucible furnaces for steel may be fired by gas or coke ; the latter form occupies less space than the gas-fired furnace, and is not so economical when a continuous supply of metal is required, because of the ease with which waste gases can be made to pre-heat the metal.

A modern type of coke-fired crucible furnace for steel is shown in Fig. 3. It is designed to accommodate four 80 lb. crucibles, and is supplied with forced draught. It takes sufficient coke initially for the complete process, which avoids loss by radiation when re-coking and makes for economy.

The electric furnace has made great headway during recent years. It is the most recent method of melting steel for castings, and its product compares favourably with crucible-melted steel. The melting is done, as in the crucible furnace, in a reducing atmosphere. The construction of the most common type of electric furnace used in the steel foundry is based on the principle that when any resistance is offered to an electric current, heat is generated ; it is this heat that is used to melt and refine a charge. While there are a

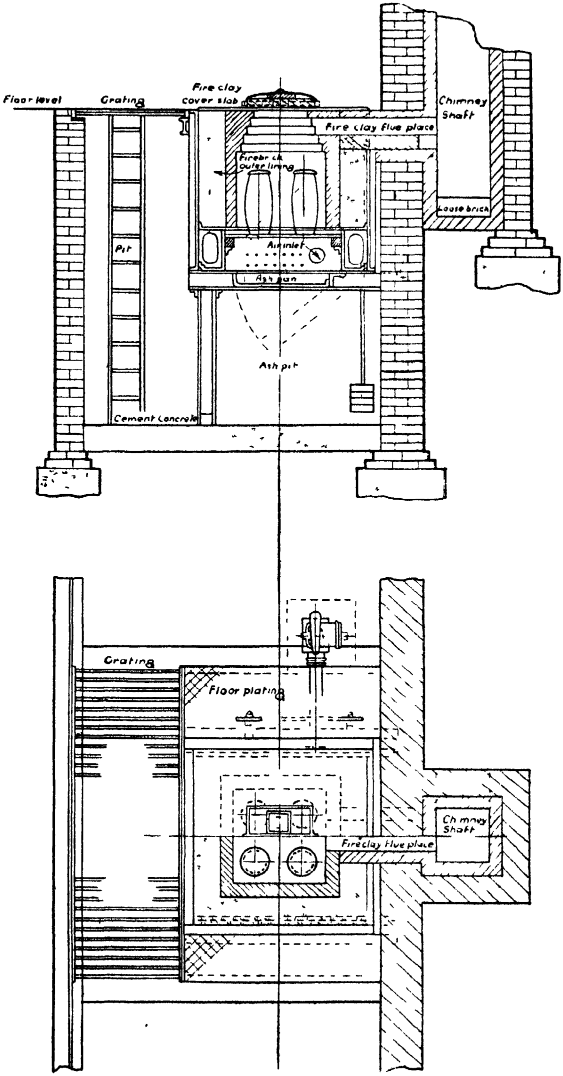


FIG. 3. ARRANGEMENT OF MODERN COKE-FIRED CRUCIBLE FURNACE

number of furnaces based on the principle, the most commonly used is the arc resistance type, one of which is illustrated in Fig. 4. In this furnace the current passes from an electrode to the charge, and through the charge to another electrode conveying the current from the furnace. More than two electrodes may be necessary to convey the current in some furnaces. They are adjustable, capable of being moved up or down. It is the metal in the charge that provides the resistance to the passage of the current, or, when the metal is fluid, the slag.

In the converter process the usual method is to melt the metal first in a cupola, although in the Stock converter the melting is done in the converter. There are several types of converters, varying in design but embodying similar principles and based on the Bessemer converter. The basis of the principle is the generation of heat due to rapid reaction. In the Bessemer converter, air enters from a blast box through bottom tuyères and passes through the fluid metal, which causes rapid oxidization of the carbon, silicon, and manganese in the charge. This type of converter needs an air pressure varying from 20 to 30 lb. per sq. in., according to the depth of charge. On the other hand, side-blown converters, like the Tropenas, Robert, or Clapp-Griffiths, do not need the high air pressure of bottom-blown converters, 3 lb. per sq. in. being sufficient. The converter may be described as a cylindrical steel vessel tapered towards the top and lined with a highly refractory material. It is mounted on trunnions, and is tilted by hand- or power-operated gear. The Stock converter, Fig. 5, is both a melting and converting plant. Oil is used as a fuel, and a blast of about 12 oz. pressure per sq. in. is supplied. It is fitted with an economizer through which the waste gases pass during the time of melting the charge, and

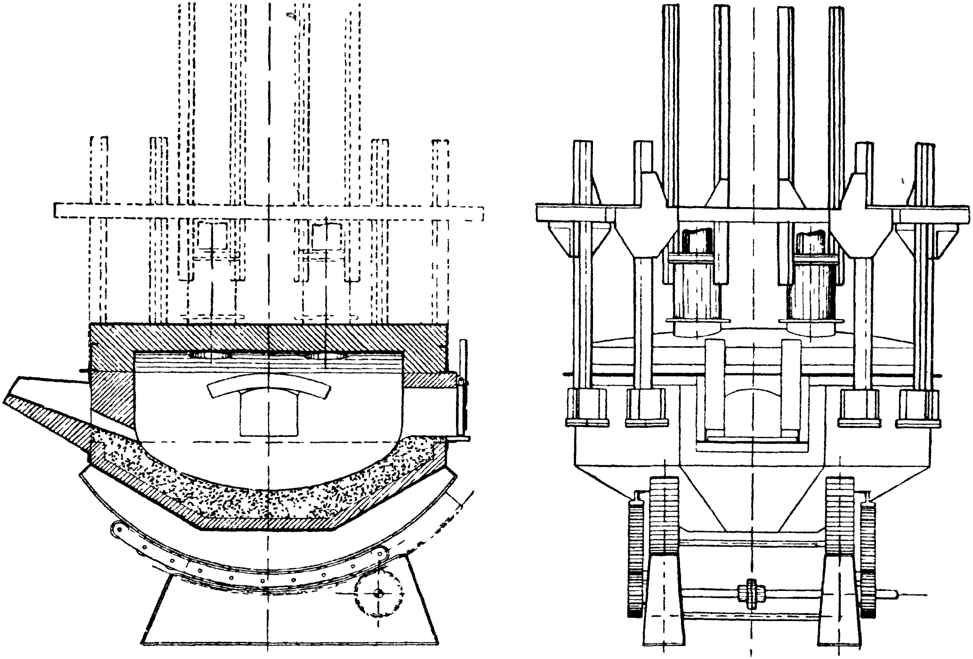


Fig. 4. Arc Resistance Furnace

which heats the blast during the time of converting the charge into steel.

The open hearth process, of which there are many types, generally melts and converts the charge. A large shallow bath is employed containing the metal, and upon this an oxidizing flame is directed. The

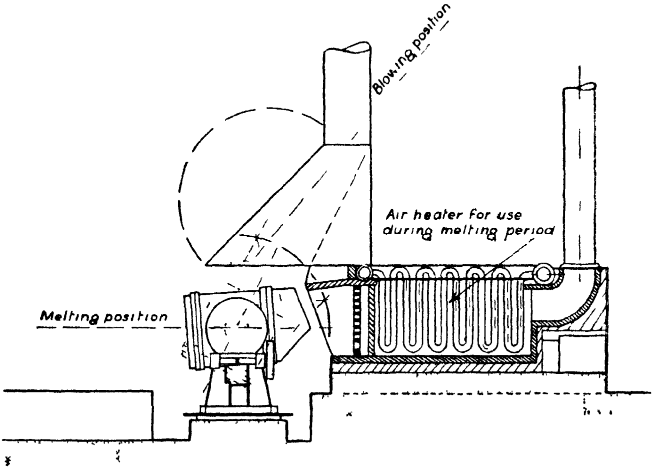


Fig. 5. The Stock Oil-fired Converter

reaction is not so rapid as in the converter, consequently less heat is generated, but the difficulty is overcome in the Siemens furnace, Fig. 6, by making use of gas as fuel and introducing the principle of regeneration. By means of regeneration the waste heat of the furnace is used to heat the air and gas before it enters the furnace. The method employed is to pass each through separate chambers built of refractory firebricks so arranged that the surface area exposed is considerable. Two pairs of these chambers are used, and they are under control so that air and gas are introduced through one pair at a time, and by operating a valve

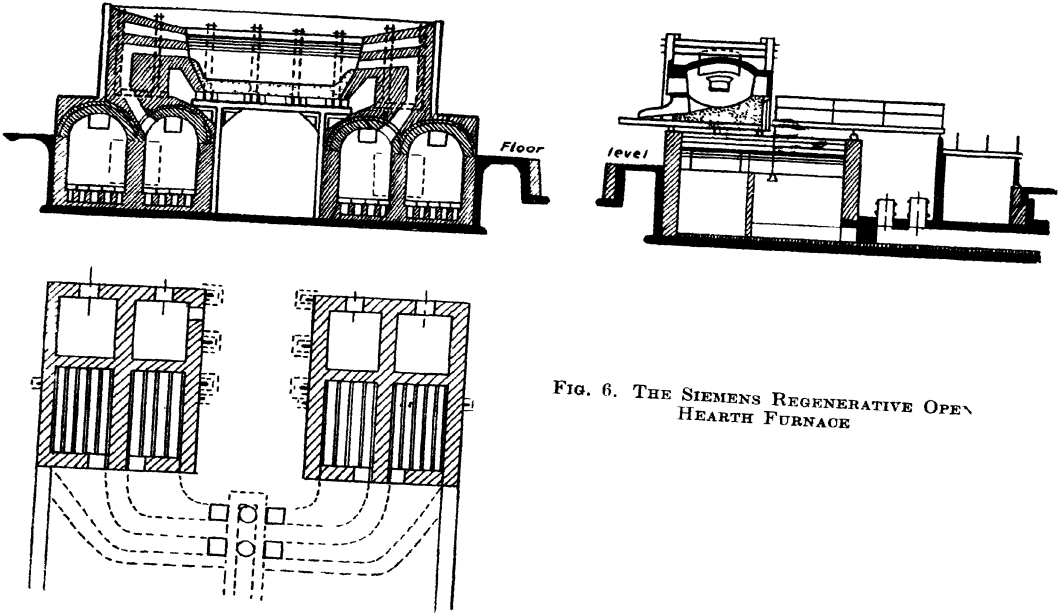


FIG. 6. THE SIEMENS REGENERATIVE OPEN HEARTH FURNACE

the pairs are used alternately at regular intervals. A special gas-producing plant is an integral part of this furnace, as the oxidizing flame is produced from a mixture of air and gas.

METAL MIXING

Cast Iron. Cast iron is the most impure form in which iron is used economically, and its value is largely due to other elements in its composition which influence its character, such that it is more readily fusible and possesses greater fluidity at a lower temperature than steel. In addition to carbon, cast iron contains silicon, manganese, phosphorus, and sulphur, and the relative quantity of these elements and the character of their association with the iron influence the physical properties of the cast iron. The composition of the various pig irons differs, and they are graded to facilitate suitable mixing when preparing a charge. In making up a charge the fracture method may be adopted. In this method the softest and weakest iron is determined by its open texture, its grey colour, and the ease by which it is broken. Between this and hard white iron, which has a close texture and is brittle, are various grades that are characterized as soft, moderately soft, tough, tough and strong, moderately hard, and very hard.

In addition to fracture, the qualities of particular brands of pig irons are more or less known ; hematites, for instance, are strong, tough irons and low in phosphorus ; cold blast irons are also strong and tough, but generally harder than hematite and more readily chilled. Apart from these two the English pig irons are usually designated as common pig, and sometimes given the county or town in which they are produced, or the trade name under which they are known. In Scotland, apart from hematite, the pig iron produced is known as Scotch pig, together frequently with a trade name.

English pig irons generally are not very strong, but possess good machining qualities and have high fluidity. Scotch pig is moderately strong and capable of taking up much scrap.

Special pig irons are available suitable for particular work, but the cost of these is higher than for ordinary pig irons. Scrap metal is variable, and while its fracture may give some guide in determining its physical qualities, the purpose for which the casting had originally been used will also assist. In making up a charge by the fracture method, the foundry depends largely on one man, and, however skilful he may be, the results are uncertain, because cast iron may have a similar fracture but vary much in its physical characteristics. The method is now largely superseded by more scientific mixing, necessitating a knowledge of the chemical analysis of the pig irons and scrap employed. This method, used in conjunction with physical tests, is the most satisfactory method. Where a particular cast iron possesses the required physical properties its chemical analysis is invaluable in maintaining uniformity in subsequent casts.

Making up charges to suit certain chemical analysis, when the composition of the pig and scrap iron is known, offers facilities for dealing with a varied assortment of castings with greater accuracy than the fracture method. Cheaper pig irons can be used, and better advantage taken of scrap when its composition

	Carbon	Silicon	Manganese	Phosphorus	Sulphur
For thin castings .	3·6–3·3	2·8 –2·5	·65–·55	1·3–1·1	·03–·04
General work of medium size .	3·6–3·3	2·25–2·0	·75–·65	1·1–1·0	·06–·08
Heavy machinery castings . .	3·6–3·3	1·7 –1·2	·85–·75	·6– ·4	·06–·08
For castings to withstand steam or water pressure .	3·2–3·0	1·5 –1·0	·7–·5	·7– ·4	·08–·12

is known. The risks in compounding a mixture are less, and faults in the composition can be traced more readily. The composition of cast iron suitable for average work can only be referred to here, and the table of percentages on page 125 will serve as a guide, the balance being iron.

In making up the charge it is necessary to define the relative contents of each kind of metal to be charged, and it should be calculated on a percentage basis, making allowances for loss of silicon and manganese and gain of sulphur and phosphorus. Some silicon is lost by oxidization, and an allowance of 0·2 per cent is generally made. Manganese combines with sulphur and enters the slag, the amount varying, but an allowance of about 10 per cent more than is required in the finished metal is generally made in the charge. Sulphur is affected by the manganese, but some is absorbed from the fuel, and an increase can be expected varying from 0·01 to 0·02 per cent. The phosphorus is not affected appreciably; the amount present in the final metal is similar to that in the charge, but the metal obtained only amounts to about 90 per cent of that charged, thus an increase in percentage of phosphorus may be expected.

The properties of cast iron are controlled by the amount, type, size, and distribution of the various carbon formations in its structure, and control of composition, particularly of carbon and silicon, is one of the many factors in accomplishing this. The principal components in grey iron structure are graphite, pearlite and ferrite. The major percentage of the carbon present is in the form of graphite. Large flakes of graphite are associated with soft, weak, grey iron, while a similar percentage of graphite, uniformly distributed throughout the mass in very small flakes, is stronger by comparison. In this condition the carbon is not combined with the iron. Some of the carbon is usually present in a combined form which produces a structure known as pearlite—similar in many respects to the pearlite found in carbon steels. Pearlite is strong and constitutes the main part of the structure of high-duty cast irons. Grey cast irons with combined carbon, within the range of 0·5 and 0·9 per cent, have a structure consisting mainly of pearlite and, when the remaining carbon is finely dispersed and uniformly distributed, they can be regarded as strong irons; when the silicon content is relatively high, however, on slow cooling, part of the pearlite will break down, and ferrite, associated with graphite, will be formed, which reduces the strength, but gives the metal a degree of ductility.

Alloy Cast Irons. With a few notable exceptions, such as high-silicon acid-resisting cast iron and the nickel-manganese austenitic cast iron, very little progress had been made in the application of alloy cast irons up to about 1930; since that time, however, the addition of alloying elements has become the basis for developments in cast-iron metallurgy and the practice is now firmly established; to-day, alloy cast irons for high-duty applications are being freely used. The object of the alloying additions may be to promote high strength properties, to resist corrosion from different media, to improve wear resisting properties, or to resist high temperatures, and alloy cast irons have been developed for these and other special purposes which possess clearly defined economic advantages in service.

The most popular alloy cast irons are those containing nickel, either alone or in conjunction with other elements such as chromium. The addition of nickel promotes a more uniform structure in castings and the difference between thick and thin sections is practically negligible; it eliminates chill and thus facilitates machining; it has a refining influence on the cast iron, which increases the strength of the iron. In cast irons for engineering purposes the desired results are obtained by the addition of 1·0 to 1·5 per cent nickel, accompanied by a reduction in the silicon content to under 1·0 per cent. Instead of reducing the silicon, both nickel and chromium may be added, usually in the proportion of three of nickel to one of chromium. Thus, for instance, the addition of 1·5 per cent nickel and 0·5 per cent chromium to a suitable cast iron gives improved strength and wearing quality. With an increasing content of nickel, the cast iron becomes harder and possesses improved wear resistance—with 20 per cent or more nickel cast irons are both corrosion and heat resisting—and thus the range of application is wide.

Chromium addition to cast iron tends to promote the formation of combined carbon, therefore strength and hardness are increased. It may be used alone in quantities of 0·25 and 0·75 per cent in grey irons, but it is frequently used in conjunction with other elements, especially nickel. The addition of molybdenum to cast iron leads to increased strength and promotes greater resistance to wear. Very small percentages are necessary to effect these improvements. For special purposes nickel and molybdenum additions are made, or chromium and molybdenum may be added as in the case of certain cast-iron roll mixtures.

A further development is the production of alloy cast irons whose properties are improved by hardening and tempering in a similar manner to steels. Unalloyed cast iron is capable of being hardened by oil quenching from suitable temperatures, and chromium, copper, aluminium-chromium, molybdenum and vanadium with or without chromium, when alloyed with cast iron, have the effect of improving the hardening properties. Nickel is a useful constituent in such alloy cast irons because of its effect in increasing the penetration of the hardening effect in thick sections. With sufficient nickel present the alloy cast iron can be allowed to cool in air.

A number of elements and combinations of elements when added to iron-carbon alloys, in suitable proportions, have the effect of preserving the austenitic condition at normal temperatures. Nickel and manganese are two of the commoner elements which have this effect; a typical composition contains 10 per cent nickel and 5 per cent manganese; some nickel may be replaced by copper and aluminium included as a constituent such as the composition containing 5 per cent nickel, 5 per cent copper, 5 per cent manganese, and 1 per cent aluminium. A more recent development of this type is a nickel-silicon-chromium cast iron containing 18 per cent nickel, 5–6 per cent silicon, 1·5–5 per cent chromium, manganese up to 1 per cent, while the total carbon is about 1·75 per cent. The austenitic cast irons find extensive use in the electrical industry on account of their non-magnetic and high resistivity properties. The high corrosion resistance properties of these alloy cast irons render them of great value in many sections of engineering and chemical industries. They are greatly superior to ordinary grey irons at elevated temperatures and resist scaling and growth; they also resist erosion.

Steel. The mixture used in the production of steel castings generally contains a low percentage of carbon and silicon; while manganese, phosphorus, and sulphur are also present as in cast iron, but to a less extent, except as regards manganese. The carbon contents usually range up to 0·5 per cent, and in the wider consideration of steel such composition would be designated as mild, but the steel used for castings is graded by foundrymen into soft, medium, and hard steel, though it must be distinctly understood that these are relative terms applied for comparison between steels suitable for castings.

For the crucible furnace the charges generally consist of Swedish bar, boiler, or ship plate, and up to about 10 per cent of hematite, while shop scrap is generally used in the charge in varying amounts. Thus, an approximate mixture of 0·3 per cent carbon steel would consist of 60 per cent boiler plate, 25 per cent ship plate, 5 per cent hematite, 10 per cent shop scrap. This method produces high-quality steel, but the heats are small. In other processes the charge is melted or converted in contact with the furnace lining, and it is necessary to adopt one of two processes, either basic or acid linings or hearths being used. In the basic furnace the lining refractory is either dolomite or magnesite. The basic process is necessary when it is desired to remove phosphorus from the charge. The acid process, on the other hand, does not reduce either phosphorus or sulphur, and it is necessary that these elements be kept very low when making the charge. The furnace lining for this process consists of silica.

Electric furnaces for steel are usually basic-lined, and involve what is known as the two-slag process, which is a better refining medium. The charge may be molten iron transferred from a converter or open hearth furnace, but usually it consists of pig iron, scrap steel, and lime, and ore and lime and mill scale are used during the refining process. Carbon dust, in the form of anthracite or electrodes, is added to recarbonize the charge. After melting, the first slag is black, this being due to oxidization of the elements in the mixture, while the second slag, which is formed largely with the use of lime for further purification and removal of phosphorus, is white.

The converter is the quickest process for providing steel. The charge is melted in the cupola and transferred to the converter, and usually consists of hematite and steel scrap for the acid process. With the basic process, pig irons of higher phosphorus content are used. With the oil-fired converter, in which the charge is first melted previous to its conversion, the charge will be similar, and is usually about 80 per cent hematite and 20 per cent scrap, ferro-manganese being added in each case after the charge has been converted to introduce the amount of carbon required in the finished charge. The melting in the open hearth furnace is done by producer or coke-oven gas and the refining by iron oxide in the form of hematite ore or mill scale. The charge consists of varying quantities of pig iron and scrap. The progress of the refining is checked by taking samples which are cooled and judged by fracture and, when it satisfies requirements, the bath is treated with ferro-manganese.

Alloy Steels. Great progress has been made in the application of low-alloy steel castings and the number of alloy combinations used has grown considerably in recent years. Nickel, manganese, chromium, molybdenum, silicon, vanadium, and copper are the main elements used, either alone or in combination. Each confers some particular advantage on the steel, but the best properties of the alloy steel are developed by suitable heat-treatment of the resulting casting.

Nickel steel castings are characterized by high strength and toughness and their ability to withstand fatigue at ordinary and at low temperatures. When present in amounts up to 5 per cent in low and medium carbon steels, nickel tends to produce a fine grained ferric structure and to refine the structure of the pearlitic areas, imparting strength, toughness, and to a lesser degree hardness. It is frequently used in combination with chromium and sometimes with molybdenum, the latter for castings required for high-temperature high-pressure service.

Manganese, when added to steel in an amount in excess of that required for the conversion of sulphur to manganese sulphide and for thorough deoxidization, is a true alloying element. The majority of steel castings contain manganese up to about 0·8 per cent, but for some years super-tough carbon manganese steel castings have been available with a manganese content up to 1·9 per cent. In the normalized and tempered condition, manganese steels of this type possess a fairly high strength with excellent ductility and compare favourably with more costly alloy steels. In combination with molybdenum a manganese content up to about 1·3 per cent gives a high tensile steel with good ductility and resistance to impact.

Carbon molybdenum steels are used for high-temperature and high-pressure conditions involving creep resistance. For such purposes the molybdenum content may be up to 0·6 per cent and low carbon is an advantage. Molybdenum may be used in combination with nickel, chromium, or copper.

Owing to the number of suitable alloying elements, the varying percentages and combinations which may be used, and also to the variety of heat-treatments which may be applied to develop specific properties, the range of services to which alloy steel castings can be applied is very large.

MOULDING MATERIALS

Sand is the primary material in the foundry because suitable mixtures possess those qualities required in the production of moulds. Economic production demands a moulding material that is plastic and capable of being formed into diverse shapes. It must be porous to free itself from gases generated during the time of casting. The mould of which it is composed should have the requisite strength to withstand the flow and pressure of the metal and yet be weak enough to crush under contraction pressure. It should be capable of withstanding high temperatures without being affected by the fluid metal to such an extent as to destroy the shape of the casting. Sand is readily obtained which, when suitably prepared, possesses these characteristics and is relatively cheap.

✓In its natural condition moulding sand is composed mainly of silica,✓ clay,✓ and iron oxide,✓ but impurities are also present in the form of lime, magnesia, potash, soda, etc.✓It is these impurities that influence the refractoriness of a moulding sand, particularly for metals having a high fusing temperature, as they fuse at relatively low temperatures and interfere with the quality of skin produced on castings. It is important that the sand used for moulds to receive steel should be low in fusible impurities, and Yorkshire and Cornish sands are frequently used for the purpose. In some instances a steel moulding sand is prepared by using silica sand and adding the requisite amount of clay to form the bond.✓ For large heavy steel castings a special mixture known as "compo" is generally employed. This consists of burnt ganister, old ganister bricks, broken crucibles, hard coke, and a clay low in impurities in varying proportions, and it is milled with sufficient water to give the desired consistency.

While a larger percentage of impurities can be tolerated in sands for cast iron, they should be low to obtain clean surfaces on castings. Erith, Mansfield, Birmingham, Doncaster, Falkirk, Clyde rock sand, and Belfast red sand are some of the sands commonly used for iron.

✓All natural moulding sands vary in strength and require to be mixed to suit the needs of particular work. The percentage of clay should be low, just sufficient to give the required strength, so that the permeability of a mould to gases will be interfered with as little as possible. Special mixtures are used to form the face of moulds, and these are backed with floor sand that has previously been used as a facing sand but has lost much of its bonding strength in contact with the fluid metal.

Sands for intricate work, especially for cores, are frequently bonded artificially; instead of using clay, one can add carbonaceous materials like linseed oil, molasses, resin, etc., as well as proprietary compounds prepared for the purpose. These bonds are more or less burnt out by the hot metal, and the sand, having its bonding strength reduced, is more friable and, in consequence, is more easily removed from castings than a clay-bonded sand.

Sands lose their cohesive qualities in contact with the fluid metal. The clayey matter is burnt, particularly that which comes in direct contact with the metal, and its strength is reduced. This is known as burnt sand, and mixes with the floor sand.✓Sand that has lost all its binding power is used for separating parts of a mould, and is known as parting sand.✓ Special parting compounds are prepared for use composed mainly of pulverized bricks, but sand adhering to castings is frequently preserved, and after being sieved, is used for a similar purpose.

Quite apart from facing sands used generally in the formation of moulds, special facings are employed to improve the skin on castings and also to facilitate cleaning. A highly refractory material is the usual medium, and it is applied to form a thin protective coat between the sand and the metal. Facings are either dusted on the moulds or applied as a wash or paint. Moulds for steel castings may be dusted with graphite or flour silica, or a combination of the two, when a dry facing is used, and similar facings mixed with water and bonded with an artificial bond or china clay when a wet facing is necessary. For very heavy work "compo" may be thinned with water and used as a facing wash. Graphite is frequently dusted as a facing when desirable for cast iron, although coal or coke dust and charcoal are also used. The wet facing for this work is generally referred to as blackwash, and consists of mineral carbon to which a bond is added and mixed with water. Graphite is a profitable addition to this blackwash.

Some iron castings require to have a chilled surface, and those parts of the mould that produce these surfaces should consist of a material that is a better conductor of heat than sand. Cast iron or a special alloy steel may be used for the purpose, and for such work the moulds consist partly of metal chills and the remainder is completed with sand.

GREEN-SAND MOULDING

Moulds may be made in green sand, dry sand, or loam, and each type calls for a sand with properties peculiar to the class of work for which each is to be employed.

Green-sand moulding infers that the mould is damp when it receives the fluid metal. The sand used contains its natural moisture or has sufficient water added to render it cohesive, and directly a mould has been prepared it is ready for casting without subsequent drying.

The main advantage associated with green-sand moulding is the rapidity in production of castings it ensures, which makes for economy in practice. It provides a more accurate definition than is possible with either dry sand or loam moulds. Steam that is generated during the time of casting is a disadvantage of this practice, since it must find a ready exit through the mould, otherwise less resistance will be offered by the fluid metal and a blown casting will result. The damp sand has a greater chilling effect on the casting than a dried mould, and a hard skin is produced on iron castings which presents machining difficulties.

Green-sand moulding has a very wide usefulness in the iron foundry, and to a less extent in the steel foundry, the size of castings produced being only limited by the risk in obtaining soundness. Generally the larger and more intricate the casting the greater the risk associated with its production in a green-sand mould.

Green-sand mixtures are weak compared with those used for dry-sand moulding, that is, the percentage of clay is lower and the moisture present assists as a bond. Both the moisture and clay present in the sand reduce its porosity and interfere with the permeability of a mould made from it: it is therefore very important that the percentage of these be as low as is consistent with strength. The facing mixtures for moulds to receive cast iron generally contain varying proportions of new and old or floor sand. The thinner the casting the lower the proportion of new sand. Coal or coke dust is invariably added to improve the skin of the castings to be produced. The amount to be added varies with the thickness of metal: thus, for light work, one part of coal dust to seventeen of sand would suffice, while for heavy work one part to seven or eight of sand would be necessary. The coal dust generates gas in the presence of the metal, which forms a thin film and prevents actual contact between the face of the mould and the metal long enough to reduce fluxing of impurities in the sand to the skin of the casting. The coal dust, in addition to being well proportioned, needs to be thoroughly mixed with the sand to obtain the best results. The facing sands for moulds to receive steel consist of new and old sand in varying proportions, but frequently a silica-sand practically free from bond is used instead of new moulding sand, and a percentage of china clay is added, according to the requirements for the particular work. No coal dust should be used in facing sands for steel, as the higher temperature apparently breaks down the film of gas and the skin of the casting is not improved.

Green-sand moulds are classified as open sand and closed moulds. The open sand mould being limited in its application, the majority of castings are made in closed or covered moulds. Open sand moulds can only be used for castings that are flat on one side and when that side can be cast uppermost. Even then, the method is only used for the roughest and cheapest of castings, because a roughened surface is generally produced in contact with the air. It is used mainly for making tackle for use in the foundry, such as foundation plates, building rings, grids, etc., but some forms of commercial castings are frequently made by this method—floor or stokehole plates, footsteps, single and double firebars, wall plates, and many castings that require to be bedded into concrete, being but a few.

Open sand moulds are generally made in the foundry floor, a level bed being formed upon which the sand is built up to the required thickness, in the case of a plate, or a pattern bedded into the floor and its surface checked with a spirit level. In the former instance the shape of the plate is invariably marked on the level bed and a sectional pattern is then employed to determine the exact thickness of the plate. When bedding a pattern in the floor, it is convenient to prepare the floor roughly and approximately level, sand is removed to make way for the pattern, which is knocked into position, checked with a level, and the sand struck off flush with its surface. The sketch, Fig. 7, illustrating this method, is a common type of mould made in this way, but three patterns are an advantage when large numbers of castings are needed.

All types of castings, however intricate, are more satisfactory if made in a closed mould ; indeed, with the majority of castings it is the only possible way. Patterns used in covered moulds are entirely enclosed, and in order that they can be withdrawn, the moulds must be made in parts that can be separated easily. The number of parts in a mould varies with the design, and moulds are referred to as two-part, three-part, or whatever number of parts is necessary to form the mould. The bottom part of the mould is known as the drag, while the top part is the cope, and intermediate parts are known as middle parts. The drag frequently consists of a number of parts.

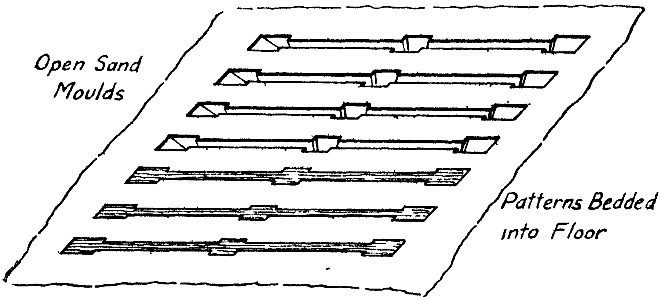


FIG. 7. OPEN SAND MOULDING

With the exception of those made in open sand, all sand moulds need to be either wholly or partially made in boxes. These are necessary for convenience in separating the mould sections and to enable their return to their relative positions without damage to the moulds. Moulding boxes or frames also serve to retain the sand within definite limits, a necessary condition, because moulds are produced by ramming the sand about patterns and to support moulds against the fluid pressure of the metal.

Moulding boxes are usually of metal, and a number of parts form one box, the parts being registered by means of pins, and, in addition they have facilities for lifting either by hand or sling. The sizes and shapes of boxes vary, depending upon the work to be made in them, and bars may be necessary to give additional support to the sand.

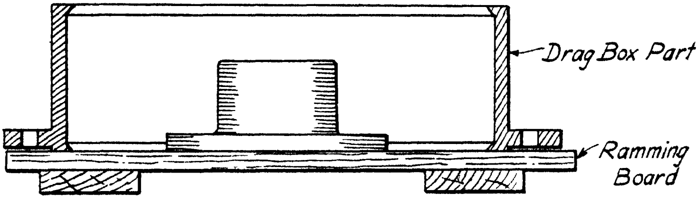


FIG. 8. PREPARING DRAG BY TURNOVER PROCESS

In order that sand moulds may maintain their shapes on the withdrawal of patterns and be strong enough to resist the pressure of metal, ramming is resorted to. The degree of density is important, particularly with green-sand moulding, and is governed by the design of the casting, the kind of metal used, and the class of mould to be made. Greater care and relatively lighter ramming are necessary for moulds in green sand than dry sand. Generally the damper the sand the lighter it should be rammed, and deep work should be dense at the bottom to withstand the pressure, but more lightly rammed towards the surface. Under similar conditions moulds for steel should be more dense than those for iron.

Moulds are prepared in green sand either by the turnover or bedding-in methods. The turnover method predominates, and consists in ramming the drag in an inverted position, and then turning-over to prepare the cope. This method gives better facilities for ramming, and ensures a more regular density.

The simplest of moulds prepared by the turnover process are those with flat joints that coincide with the joints of the moulding boxes and which have the whole of the mould in the drag, as in Fig. 8. The pattern is located on a ramming board and surrounded by the drag box-part, in which position it is rammed with sand. When the drag has been turned over, the cope box-part can be located and sand rammed in it. When the pattern is jointed in symmetrical halves the drag and cope carry equal parts of the mould, as in Fig. 9. This, too, is a simple form of mould in which the joint coincides

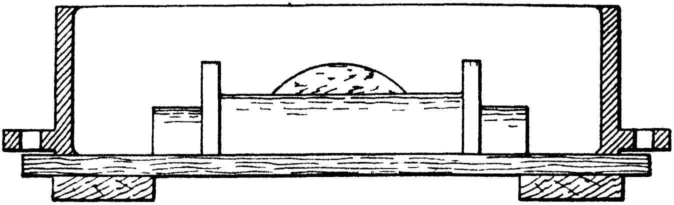


FIG. 9 PREPARING DRAG

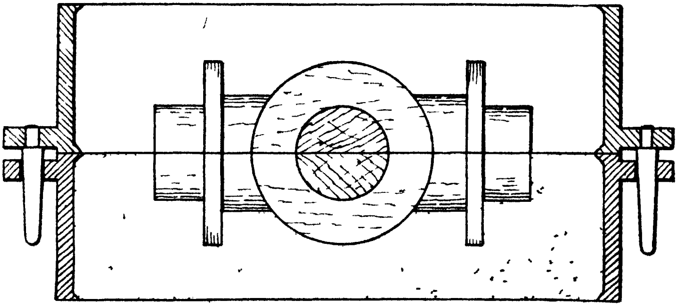


FIG. 9A. PREPARING COPE ON THE DRAG

with the box joint. When the mould joint is variable a ramming board may be inconvenient, or it may involve considerable expense to prepare ; a false part or oddside may be prepared in sand, which serves as a ramming board and determines the joint for the mould. This is only a temporary expedient, though the oddside may be used a number of times, and is often adopted when a pattern is unjointed, as in Fig. 10.

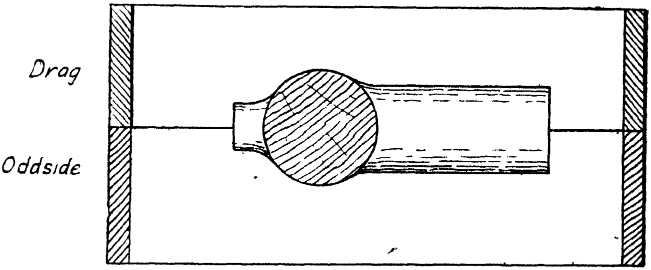


FIG 10. USING AN ODDSIDE FOR PREPARING DRAG

When a three-part mould is prepared by the turnover process it is generally convenient to commence with the middle part, as in Fig. 11, adding the next part to form the complete drag before turning over to prepare the cope, as in Figs. 12 and 13. Sometimes the extra mould part is dispensed with when the pattern is jointed conveniently for drawing into spaces from which sections have been released, as in Fig. 14. A better way, however, is to make a temporary joint flush with the flange, withdraw the flange pattern, and locate a flat core over the print and on the temporary joint, as in Fig. 15, then the mould can be completed as a two-part mould.

Considerable attention must be given to venting in all green-sand moulds, which means that gases generated during the time of casting must be directed in channels least injurious to the resulting casting. The

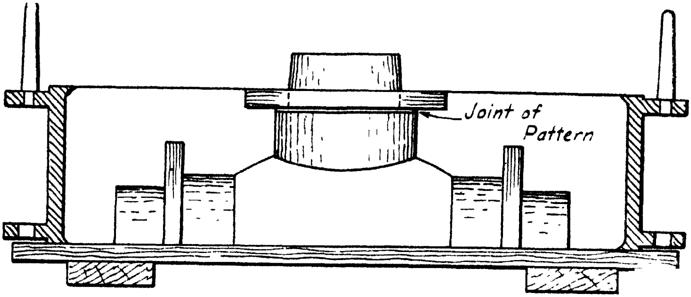


FIG. 11. COMMENCING WITH MIDDLE PART

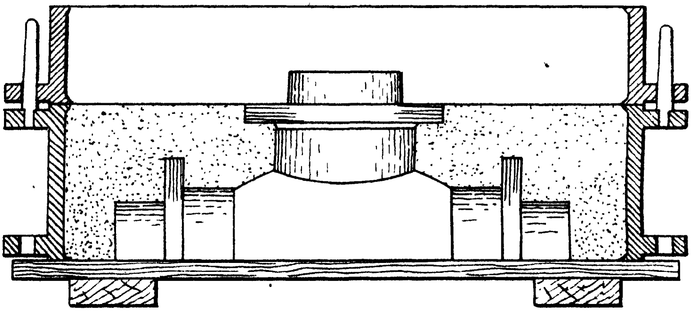


FIG. 12. COMPLETING DRAG

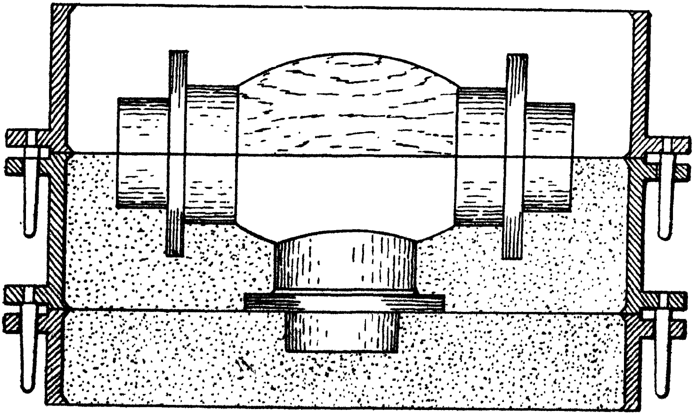


FIG. 13. TURNED OVER TO PROCEED WITH COPE

vent wire should be used, and in some instances a special exhausting chamber is necessary, as in Fig. 16.

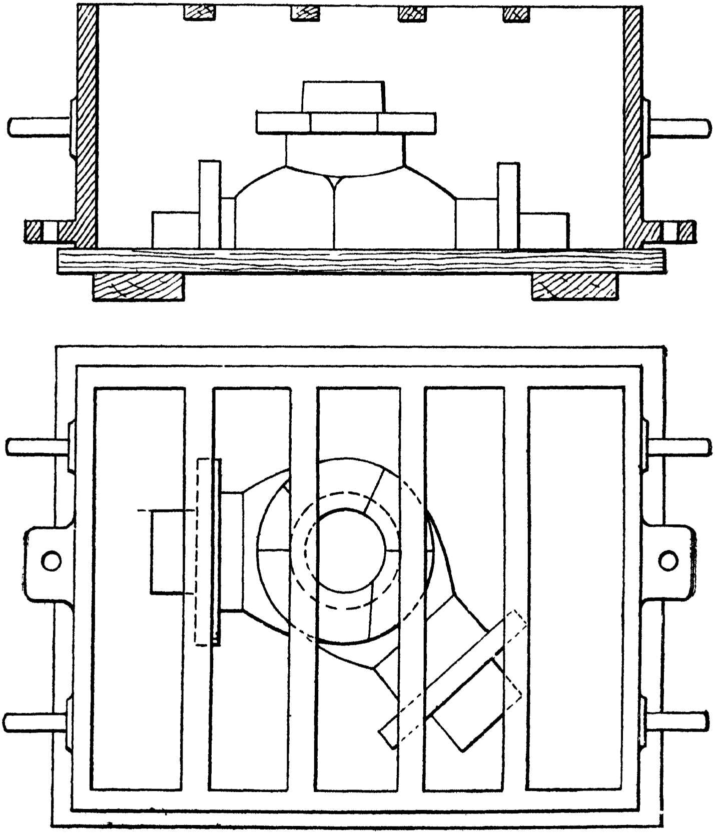


Fig. 14. Drag as One Part

Flange in sections for drawing into mould

This is usually formed with ashes under the mould when the foundry floor is used for the drag, and when escaping gases are likely to pass through the metal unless this precaution is taken.

DRY-SAND MOULDING

The term dry-sand moulding is applied to sand moulds that are dry when they receive the fluid metal. The sand used is damp, as in green-sand moulding, indeed, it generally carries more moisture to facilitate working, but more clayey matter is necessary in the sand mixtures in order that the dried moulds may have the requisite strength. There is less risk in the production of castings in dry-sand moulds and, because of this, medium and large castings in iron and a wider range in steel are usually cast in dried moulds. It is a more expensive method, as it involves the cost and time of drying, but this is compensated by the production of sounder castings possessing better surfaces than from green-sand moulds. Special mixtures of sand are prepared for the face of dry-sand moulds consisting of new

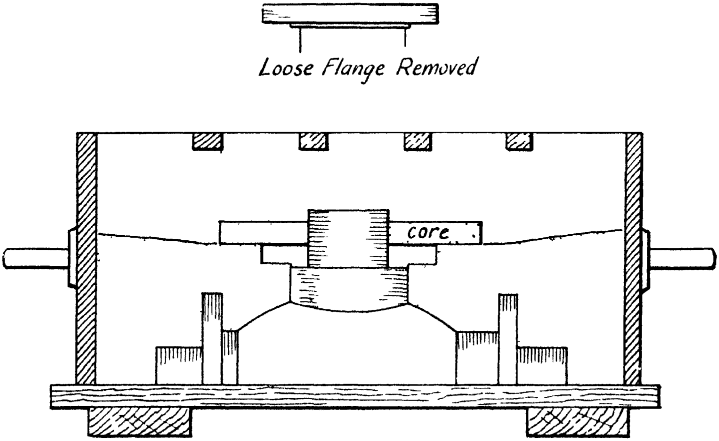
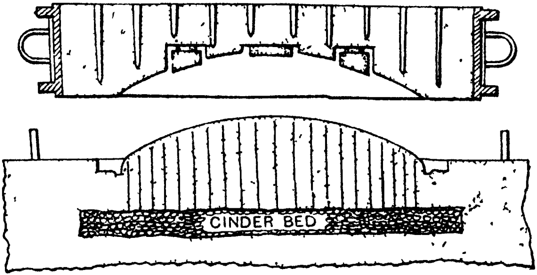


Fig. 15. Preparing Temporary Joint and Using a Core

and old sand for cast iron, in varying proportions; clay may be added to supplement the strength, or, on the other hand, sharp sand may be necessary to reduce strength.

Loam that has been used in loam moulding is frequently used in dry-sand mixtures. Coal dust is not necessary in these mixtures, because the mould receives a facing wash to improve the skin on the casting. Facing mixtures for steel vary much, and may consist of a silica sand mixed with old sand and china clay. Fireclay may be used as a bond, or varying proportions of compo may be added to old sand and milled with sufficient water to render it cohesive. The facing sand is backed with floor sand, and ramming is resorted to as in green-sand moulding, to obtain the requisite density. There is more latitude in ramming dry-sand moulds, since all moisture is removed before casting, but venting is very necessary to relieve the casting from pressure of the gases.



FIGS. 16 AND 16A. VENTING MOULDS

Moulds are prepared by the turnover or bedding-in processes, preference being given to the latter method in coping with large work. Large castings are rarely required in sufficient quantities to warrant the making of special boxes to adopt the turnover process, and consequently the foundry floor is generally used for the major part of the mould, a box being used only for covering, and this is frequently shallow and capable of being used for a wide variety of moulds.

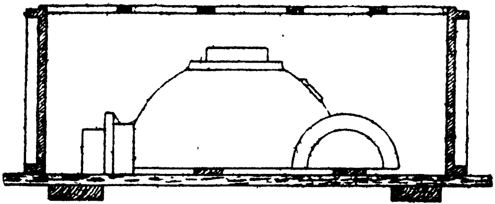


FIG. 17. PREPARATION OF DRAG FOR REGULATING VALVE

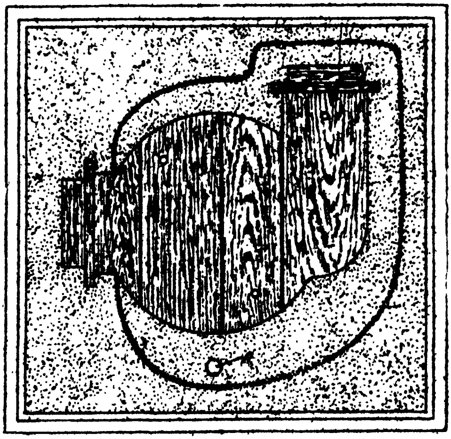
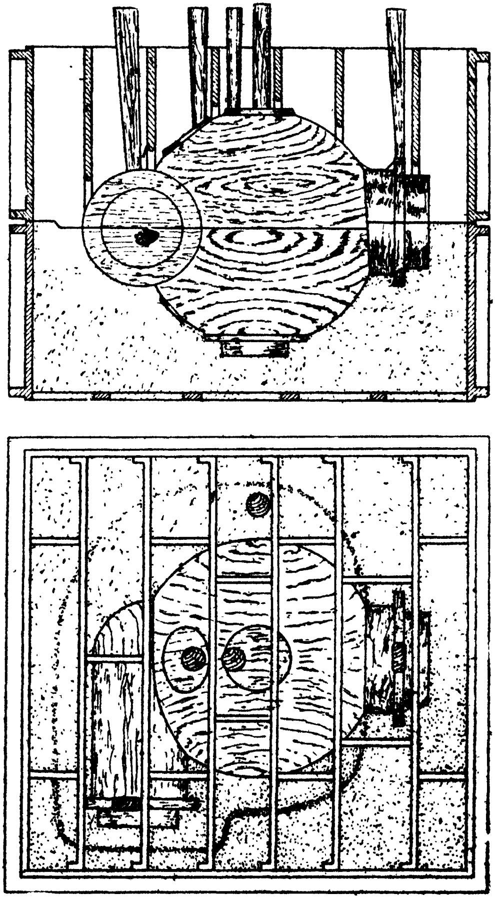


FIG. 18. COMPLETED JOINT

Within limits, it is profitable to make use of the turnover method if box equipment is available. The underlying principles do not differ from those involved in green-sand moulding, although ramming boards are largely used, excepting in small and medium sized work in the steel foundry, as in Fig. 17. This indicates the preparation of the drag for a regulating valve to be cast in steel. In this instance a dropped joint is necessary, and the half pattern is levelled preparatory to



Figs. 19 and 20. Cope Box-part Ready for Ramming-up ramming the drag. When completed and turned over, the joint is formed as in Fig. 18, and the cope box-part located, together with runners and risers ready for ramming-up the cope, as in Figs. 19 and 20. The floor is generally used instead of a ramming board. It is either levelled or shaped to conform with the pattern section or the required joint of the mould. The preparation of such a bed to receive a large steering gear pattern is shown in Figs. 21 and 22. The two logs *A A* have the required shape of the bed, and are set in the floor and checked very carefully for accuracy before sand is rammed between them and struck off flush with their surfaces. The logs are removed and their impressions filled in before locating the pattern, as in Figs. 23 and 24. It will be noted in Fig. 24 that the bed conforms to the main shape of the pattern, and subsidiary parts are let into the surface which show these particulars very clearly.

When the pattern has been located the drag box-part is lowered in position, and is then rammed up preparatory to turning over.

The expression "bedding-in" is applied when the bottom section or the pattern as a whole is bedded into a prepared position in the floor. Its wider application concerns the preparation of all moulds in positions in which they are cast without turning over. A hole is made in the floor, facing sand introduced, and the pattern section pressed or hammered down until its surface corresponds to the required level with regard to the floor level. It is necessary to withdraw the pattern and check the density of sand, adding and removing sand to obtain regular density, and then return the pattern. The sand under the pattern cannot easily be rammed, unless the shape allows access for the rammer, consequently care is necessary to obtain the density of sand desirable.

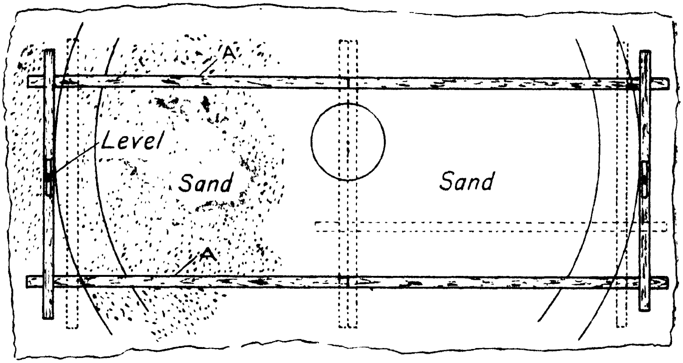


FIG. 21. BED TO RECEIVE STEERING-GEAR PATTERN

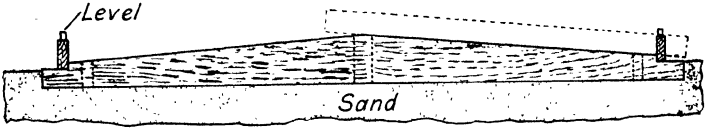


FIG. 22. BED SEEN IN ELEVATION

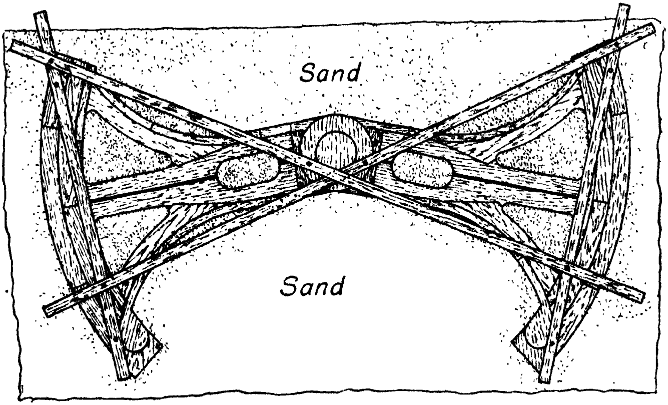


FIG. 23. PLAN OF PATTERN IN POSITION

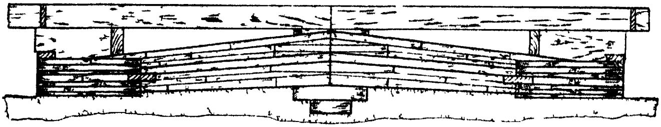


Fig. 24. Elevation of Pattern

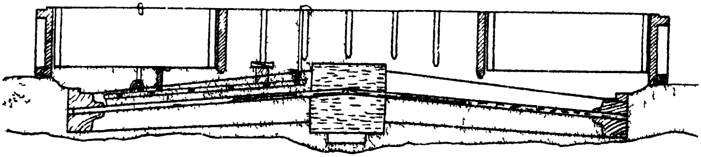


Fig. 25. Cover Box

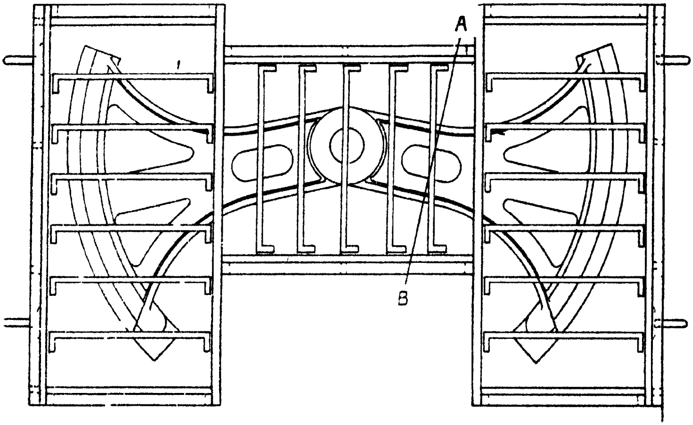
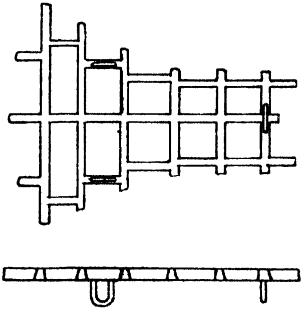


Fig. 26. Plan of Cope Box-part

To overcome the disadvantage of unequal density it is preferable to make a bearance or bed to receive the pattern, adopting a similar method to that illustrated in connection with the turnover process, but at a distance from the floor level, which will allow for practically the full depth of the pattern. The pattern is allowed to rest on this bearance, subsidiary sections being let in and the outsides rammed to the full depth of pattern from which a mould joint is made to the floor level, and within the capacity of a cover box, as shown in Fig. 25. The cope can be carried in a single or built box-part, depending upon equipment available,


FIGS. 27 AND 28. GRID

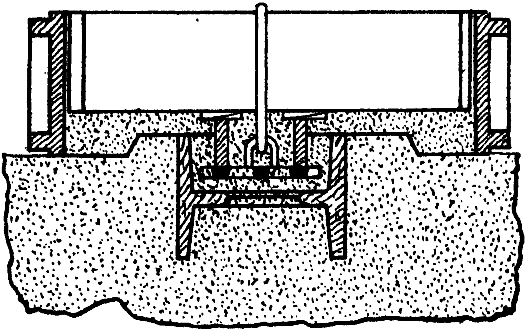


FIG. 29. GRID FIXED IN POSITION

and Fig. 26 is a plan of the cope box-part in position. Generally much sand must be carried beyond the box joint, and this needs reinforcement and some attachment to the cover box. Soldiers or gaggers maybe used, but in this instance a grid, like Fig. 28, is preferable. It is generally coated with claywash and bedded in sand covering the pattern. In this position it is hooked to convenient box-bars and wedged, as shown in Figs. 26 and 29. A section of the mould on the line *AB* is shown in Fig. 29, which, in addition to showing the grid, also shows the position and shape of the mould joint.

LOAM MOULDING

The use of loam as a medium for making moulds has been common since the Middle Ages, and though in modern practice there is a tendency to eliminate it in favour of dry or green sand, there are conditions under which loam moulding will always hold economic advantages over either dry- or green-sand moulding.

Loam has wide applications, and may be used to build a complete mould, including cores, or a loam pattern may be formed from which a sand mould is prepared. Its use is profitable when the number of castings of similar design do not warrant the making of a full pattern, and are of such a character that loam can be used. Loam is strong, plastic, and needs no ramming. A cheap profiled-edged board takes the place of a costly pattern, or instead, a skeleton pattern may be employed, according to shape required. While the pattern as a whole may be of loam, subsidiary pattern sections are made in wood and located on the loam work.

Moulds in loam require to be dried, and are coated with a facing wash before being cast. Much tackle is involved in the making of loam work, and this adds to its expense in the foundry. Loam is a strong moulding sand, having sufficient water milled with it to make it the consistency of mortar. Usually two mixtures are used in moulds for iron—building and facing loam.

Common or building loam forms the major part of a mould, and is used between bricks or over grids or plates used in building, while the facing loam forms the face of the mould. Mixtures vary, but owing to the strength it is necessary to introduce openers to increase porosity. For this purpose chopped straw, horse dung, sawdust, or cowhair may be introduced. Ground coke or sharp sand may be added to weaken a mixture as well as to increase porosity.

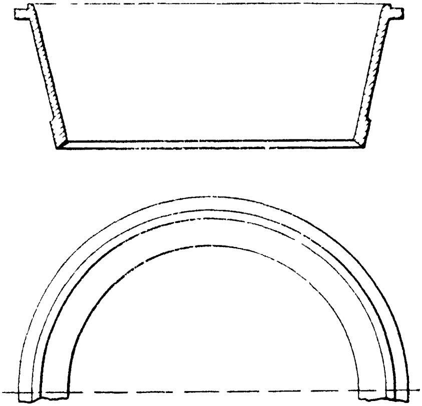


FIG. 30. CASTING SUITED FOR SWEPT MOULD

The principles involved in the preparation of moulds for steel are similar to those for iron with this difference, that the greater heat of the metal demands a facing mixture of high refractoriness, and compo is usually introduced in the mixture, but a high-quality silica sand bonded with china or fireclay would meet the needs of average large work.

A type of casting for which a swept mould is particularly suited is shown in Fig. 30. It represents a section and half plan of a blast furnace hopper, and is usually of steel. The height of the work is short compared to the diameter, and, because of this, the mould can be swept about a vertical spindle. A machine-turned spindle, not less than 3 in. diameter, is fitted into a socket, which is fixed to the bogie plane and upon which is supported a building plate. The spindle rotates in the socket, and tail pieces or spiders are fixed to the spindle. The spiders carry the sweep, it being fixed by bolts or clamps, so that when it rotates with the spindle the profile of the sweep defines the cylindrical shape required, as in Fig. 31. Bricks are built up to within about 1 in. of the sweep when a facing compo is applied and swept to shape, the facing being thinned with water and thrown over for a final sweeping. When this has been dried, or allowed to stiffen, another sweep is attached to enable a thickness of sand to be applied to the mould equal to the thickness of metal in the casting, as in Fig. 33. This is termed the core-board. It is not essential to have two sweeps ; a core-sweep with a wood thickness on its face to form the mould profile

FIG. 32

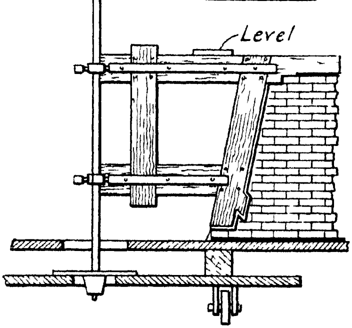


FIG. 31. CORE-SWEEP

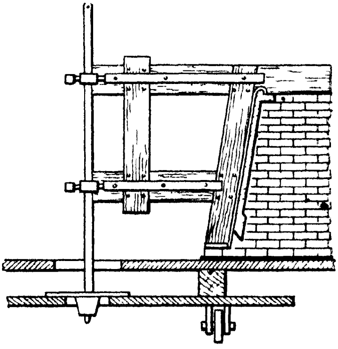


FIG. 33. CORE-BOARD

would suffice, as in Fig. 32. Sweeps for use on compo should be reinforced along the edge with iron strips. When the thickness has been applied and is dry enough

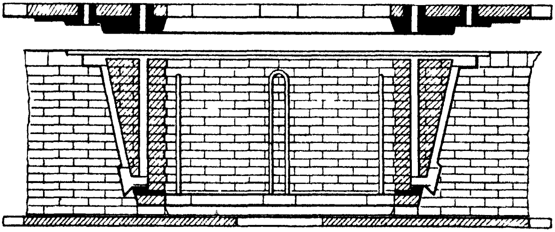


FIG. 34. CORE BUILT INSIDE COMPO

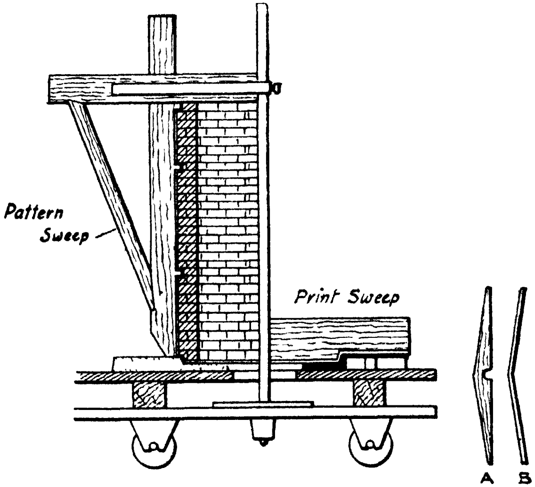


FIG. 35. SWEEPING OF CYLINDER PATTERN

the core can be built inside, as in Fig. 34. On subsequent drying and lifting the temporary sand thickness can be removed and the core replaced, as in Fig. 34. The cover is prepared in place after building the core, and while the sand thickness is still in position.

Building a cylindrical pattern in loam about a vertical spindle is similar, excepting that the sweep rotates outside the brickwork. Fig. 35 shows the sweeping of a cylinder pattern. A seating or print board is first used to provide a seating for the core—this part becoming part of the mould—and the pattern is built on it. The gauge stick *A* is used to assist in setting the sweeps and in checking after sweeping, but by building in a couple of gauge irons *B* at reasonable distances from top and bottom of the pattern an excellent check is provided against movement of the sweep while building. This form of pattern is used in dry sand, it being lowered into a case or pit in the floor and subsidiary pattern work temporarily attached, as in Fig. 36, preparatory to ramming. The loam pattern is broken out when stripping; thus, if two castings are needed, two patterns must be swept.

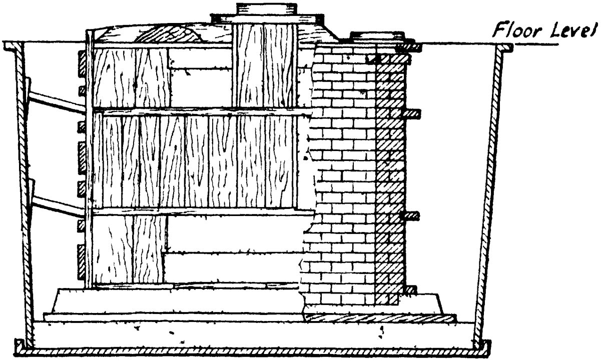


FIG. 36. CYLINDRICAL PATTERN READY FOR RAMMING

Another form of sweeping is necessary when work is long compared to its diameter; thus the mould for the large cylindrical retort shown in Fig. 37 can be swept by means of a board secured to a horizontal spindle which rotates in bearings, as in Fig. 38. In this instance the brickwork is built in a box or frame, and wood half-flanges are used on which the sweep rides. After the mould has been swept and either wholly or partially dried another sweep is used to add a thickness of sand similar to the metal thickness. This forms a half core-box in which the core can be built and struck off with a sweep in the manner illustrated in Fig. 38. To strengthen and support such a core a built barrel grid may be used for which a number of slotted plates are

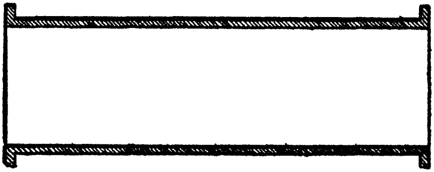


FIG. 37. MOULD FOR CYLINDRICAL RETORT

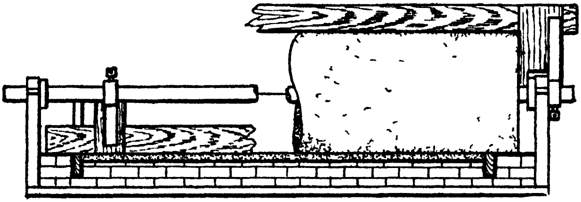


FIG. 38. SWEEPING BOARD WITH HORIZONTAL SPINDLE

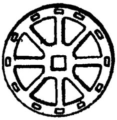


FIG. 39

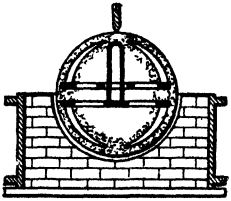


FIG. 40

made, like Fig. 39, and bars slotted through them, but usually two grids with shaped gaggers are used as

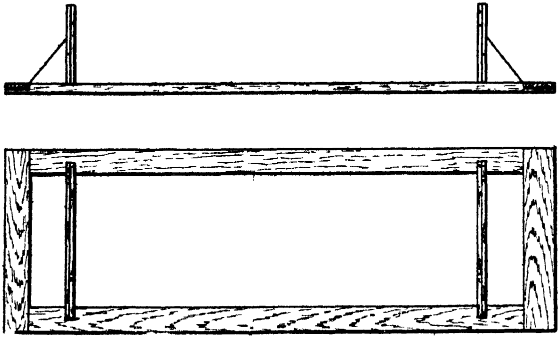


FIG. 41. FRAME FOR RETORT CASTING

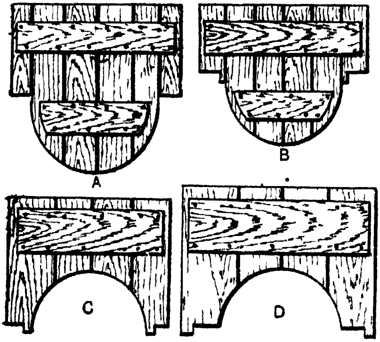


FIG. 42. STRICKLES

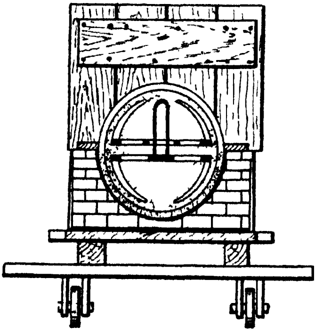


FIG. 43

shown in the sectional elevation, Fig. 40. When the core has been built, a thickness is applied to form a pattern in order that the top of the mould can be prepared in position. A simple frame carrying half-flanges, like Fig. 41, may be supplied for the retort casting. The frame acts as a guide for the strickles, shown in Fig. 42.

Thus *A* would sweep out the bottom half of the mould between the flanges, while *B* would be used to apply a sand thickness. The half flanges are then stripped and reversed on the frame, when the core can be built and struck off to shape with strickle *C*, the sand thickness being added and shaped with *D*, as in Fig. 43. The plate can be removed, the flanges returned, and mould cover made.

Much work of this character can be prepared from a loam pattern swept on a drum or spindle, as in Fig. 44. The spindle is usually hollow, and of a diameter comparable with the size of work to be swept on it. Journals are fixed centrally at each end to allow it to rotate in bearings carried on trestles. A sweep having the desired profile rests on the trestles, and is fixed at the proper distance from the centre of the spindle. The spindle is then rotated, and straw rope is wound on the drum or barrel together with loam. This process is continued until the straw rope conforms somewhat with the shape, but allowing for about ½ in. of loam to be applied for final sweeping. The loam is made as thin as possible for final sweeping, so that the surface will be smooth when dried. Subsidiary wood pattern work can be attached to this loam pattern, and the whole used to produce a mould in dry sand. Such a pattern can be used many times with reasonable care.

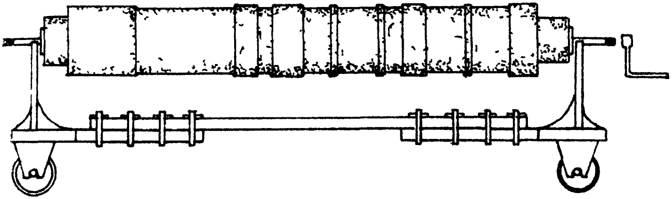


FIG. 44. LOAM PATTERN ON HOLLOW SPINDLE

CORES AND CORE-MAKING

Core-making is usually referred to as having particular reference to the central shape of the casting. Although this is suitable as a general expression, in practice it is applied to any body of sand prepared separately and introduced into a mould after the pattern has been withdrawn to define shapes not formed with the pattern. The expression is also used for shapes prepared in the mould in such a manner that they can be lifted separately.

Generally speaking, when the pattern-maker supplies suitable facilities for making the body of sand of the required shape (whether by means of a core-box, core-frame and strickle, core-plate and strickle, or skeleton shell pattern) the term core is applied, but when a full pattern is supplied from which the internal, as well as the external, shape of the casting is obtained, when the pattern is withdrawn from its mould, the central body of sand is frequently referred to as a "cod," and this term is often used, even though it may be lifted temporarily.

There is another type of core for which the moulder is mainly responsible as no facilities are supplied to him other than the pattern. This refers to loose parts of a mould which are so made to free the pattern and permit its withdrawal or to introduce other cores. In such cases the moulder determines the shape of the loose parts and is guided only by the pattern. These loose parts of the mould are sometimes referred to as "false cores," though they are more generally termed draw-backs. To prevent any confusion in the use of these various terms, references in this section will be confined to cores which are made separately and to those made in the mould from skeleton shell patterns.

Why Cores are Used. The use of cores may be regarded as a necessity or as an expedient, bearing in mind that the object is to produce a sound casting of desired shape at the minimum cost. They are a necessity when the production of a mould would be impossible without their aid, or when the central part of a mould, formed from a pattern corresponding in shape

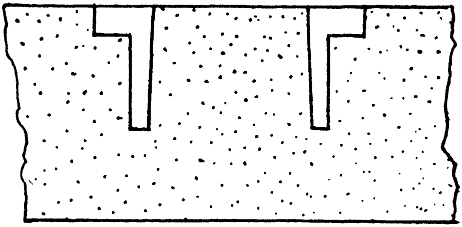


FIG. 45

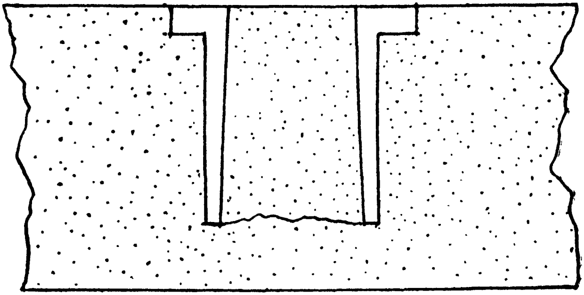


FIG. 46

with the required casting, would be too weak to withstand the rush and pressure of the metal at the time of casting, or when the construction of such a pattern would render it too weak as a pattern. The mould for a simple gland, for instance, as in Fig. 45, may be made without a separate core if the internal diameter is large enough compared to its length and adequate taper is given so that the pattern can be easily withdrawn. If, however, the diameter is small compared to its length, as in Fig. 46, it is difficult or impossible to withdraw the pattern without destroying the central shape, even though excessive taper may be given to the pattern. There is no such difficulty when the central body of sand is made separately as a core and located in the impression left by the core print on the pattern, as in Fig. 47, and incidentally the hole is parallel, which reduces the subsequent machining of the casting.

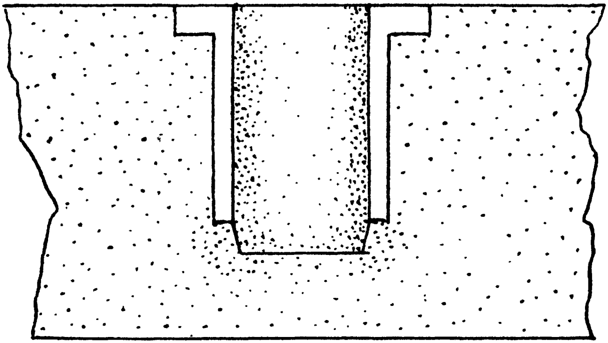


FIG. 47

A more difficult example, although in principle similar, is illustrated by the mould for a valve, shown in Fig. 48. It would be extremely impractical to attempt to make moulds from a pattern formed as a model of the finished valve, but by preparing the mould for the external shape and a core to form the internal shape, the parts are readily assembled to form the complete mould.

Whether simple or intricate the majority of castings require cores in the formation of their moulds in order to reduce the difficulties encountered in the manipulation of sand and also in order to reduce the time expended in the preparation of one or many moulds according to circumstances. The wall bracket in

Fig. 49, for instance, could have its mould prepared from a pattern similar to the casting, but it is expedient to make use of a core, as in Fig. 50, because the method enables the use of a stronger pattern and it gives a more accurate and cheaper casting, especially if a number are required.

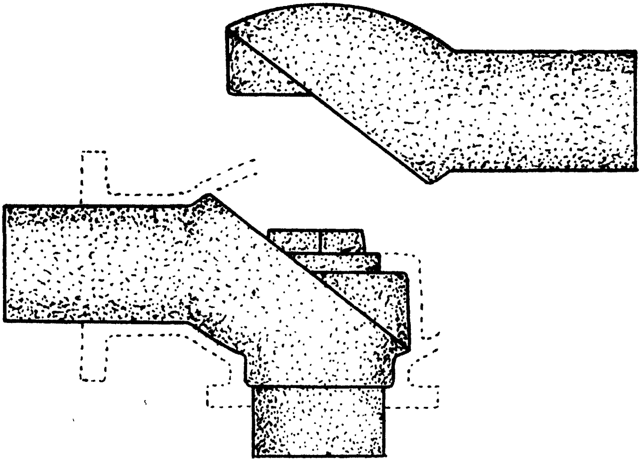


FIG. 48

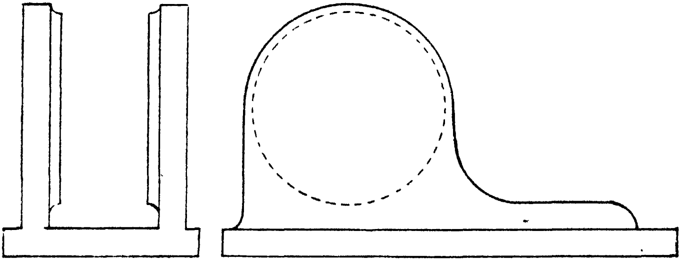


FIG. 49

Although the use of cores leads to economy in production when quantities of similar castings are required, in some cases cores may be used when only a few castings are necessary and a full pattern supplied for

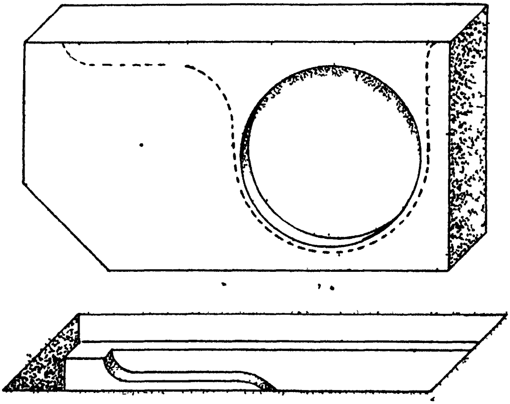


Fig 50

quantities. Thus, a mould for a large wheel is usually prepared in cores, the number depending upon the number of arms in the wheel. The mould and cores for such a wheel are shown in Fig. 51. Other instances in which the use of cores is expedient are shown in Figs. 52 and 53. The former shows a section of a mould for a rope pulley, the groove being cored out to facilitate moulding, whereas in Fig. 53 is a section of a mould for a worm wheel, the teeth of which are formed by cores. In these instances cores are used not only to reduce the amount of jointing which would otherwise be necessary in the preparation of the moulds, but also to expedite production.

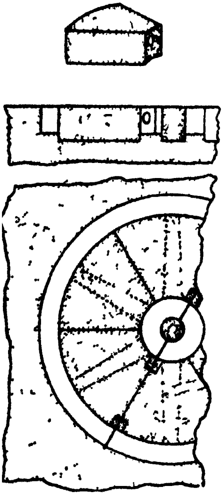


Fig 51

Core-making Materials. Generally, greater care is necessary in making cores than in making moulds, because, as a rule, a relatively greater part is in contact with metal at the time of casting, there is, therefore, less room for gases to escape. The sand forming the core must be strong enough to maintain its shape before the rush and pressure of the metal, but, at the same time, it must be weak enough to allow the casting to contract and to facilitate its removal when the casting is cleaned.

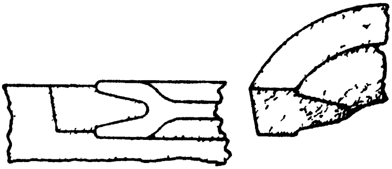


Fig 52

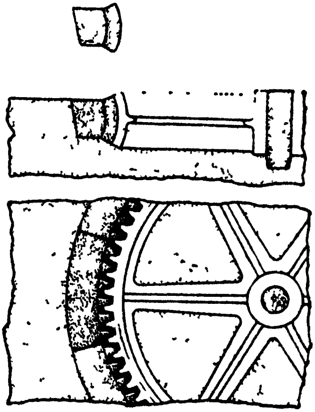


Fig. 53

Naturally bonded sands are used to a great extent, especially for larger cores, and those parts which form a facing for the metal are given a special facing wash to improve the skin of the casting and, more important, to help the sand to peel from the casting. Clay-bonded sands, however, become fairly hard when burnt, through contact with the metal, and in many cases it is necessary to weaken the structure of the cores in order that they will offer less resistance to contraction and also to enable them to disintegrate easily. Grading is necessary according to the metal to be cast and the size and intricacy of the work.

For small and intricate work artificially bonded sands are now in common use. The use of oil as a basis predominates, and it is preferable when mixed with washed or sea sand; water and oil may be emulsified and the sand dried before mixing, but this is not essential. The oil may be spread over the damp sand and roughly mixed by hand before putting it through a mechanical mixer. The use of a carbonaceous material, such as linseed oil, facilitates cleaning, as the bond is burnt in contact with the metal, leaving the sand fragile. The amount of oil to sand is variable but, for general work, one of oil to forty of sand, by volume, is suitable. For steel castings it is necessary to increase the proportion of oil and the use of washed silica sand is advisable. Molasses makes an excellent artificial bond for core sands, and in many proprietary bonding mixtures it is used as a base.

Naturally bonded sand or loam mixtures are more generally used for cores in the iron foundry. They are cheaper and the cost of bonded strength is undoubtedly a guiding factor, but there is an increasing tendency to use artificially bonded sands for this purpose, especially for work of a repetition character, because mixtures can be economically prepared to suit the work. Generally the smaller and more intricate cores need a stronger, bonded sand, whereas larger cores need less bond because of their bulk, which assists the core in maintaining its shape. In the making of large castings core loam, which is naturally bonded sand used in a more plastic state than core sand, is not likely to be displaced because it is readily prepared and it can be used with all types of core-boxes. Mixtures for core sand vary considerably, but some general considerations can be given relative to artificially bonded sands. It is better for instance that the sands used should be as free as possible from clayey matter, such as are known as weak sands, and generally it is advisable that they are dry when the bond is added.

Core sand should be thoroughly milled or mixed by mechanical means to ensure thorough incorporation of the bond with the sand. With clay-bonded core sands and core loam mixtures, carbonaceous materials may be added to make them more open in texture after being dried. Coke breeze or sawdust may be ground with the mixture for this purpose, while cowhair or chopped straw may also be used; these latter, in addition to being effective as openers, make the sand more porous and also act as bonds.

Owing to the high temperatures of the molten steel, the most refractory sands are necessary for cores used in the steel foundry. Steel moulders' "compo" is commonly used in Britain, particularly for large cores, because of its heat resisting qualities. It forms an exceedingly strong core and, although the strength can be varied, it is too coarse for smaller work. Thus, for other than large work silica sand or a sand such as the Yorkshire variety, which is comparatively free from impurities, is used. The silica sands must be of high grade and china clay or carbonaceous bonding materials added to give the requisite strength when mixed. Large cores are usually coated with tar and dried, but small cores are given a wash with a mixture composed of silica flour and water in which clay is added as a bond; sometimes graphite is also added to improve the skin of the casting.

Green-sand, Dry-sand, and Loam Cores. Just as in the case of moulds, which receive the molten metal while in a green state, i.e. the sand containing its natural moisture, cores are sometimes used in green sand. The same difficulties are experienced with green-sand moulds, but they are accentuated because the core is usually enclosed in the molten metal to a greater extent at the time of casting and the outlet for the escape of steam and gases is correspondingly reduced. Generally, dry-sand cores are used when the risk of producing waster castings is greater than the saving of time obtained from the use of green-sand cores. This does not mean that there is no case for the green-sand core, but that there are limitations to its usefulness in the iron foundry and particularly in the steel foundry. They can be profitably used in green-sand moulds of a repetition character when the area to be in contact with the metal leaves ample room for venting.

With the exception of the relatively few cores used in a green or skin dried state, all cores, whether made in dried sand or loam mixtures, are dried. The term "dry sand" refers to the condition of the sand when it receives the molten metal; the mould or core is prepared from the sand mixtures while it is in a green state, but it is strong by comparison with green-sand mixture and it must be dried. Normally moulds and cores made in naturally bonded dry-sand mixtures are dried to remove the moisture content, whereas cores made from artificially bonded sands are baked and greater attention must be given to the temperature of the ovens in which they are baked.

In making the smaller cores with oil-bonded sands they should be handled as little as possible, as the cores are very fragile in a green state. It is better to make use of a warmed plate when the sand comes directly in contact with it during the time of making the core. This stiffens the sand and facilitates stripping. For cores that do not rest flat it is advisable to have drying receptacles corresponding to their shape to hold them during the time of drying, a perforated shaped plate used for this purpose being shown in Fig 54. Larger cores need not consist wholly of oil-sand, only sufficient being necessary to form the face, say a thickness of about $1\frac{1}{2}$ in. to 2 in, the inside being filled with old sand, and cinders may be used. Cores so made should be vented to ensure the escape of steam when drying, as the outer oil-sand becomes very hard. Irons are necessary for ease in handling, but there is less need for them to support the cores than when using naturally bonded sand. This applies also to venting, oil-sand cores needing less venting, though this

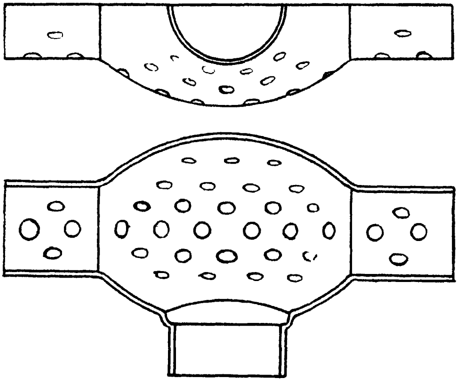


FIG. 54. TWO VIEWS OF CORE DRYING PLATE

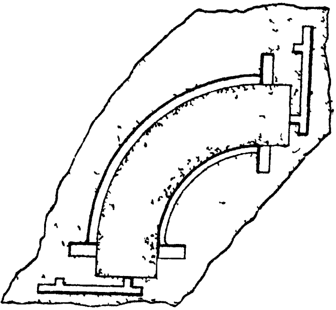


FIG. 55. GRID FIXING

requirement should not be overlooked unless the cores are small. Waxed string for venting irregular cores of intricate shape is very helpful.

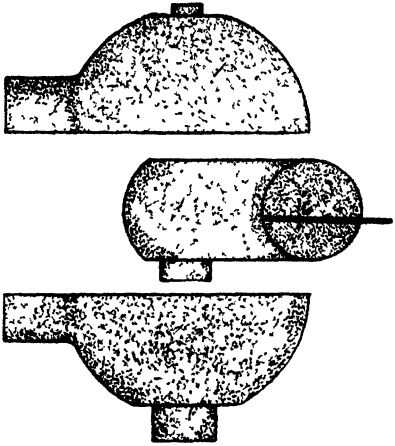
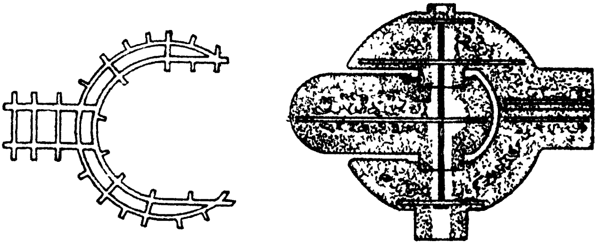


FIG. 56. THREE-PART CORE

Cores made from naturally bonded sands, unless very small, require to be wired, rodded, or strengthened by the introduction of a grid, and much attention must be given to the form of support a core needs. Sometimes the grid or iron is carried through the core to maintain its position in the mould, as in Fig. 55, and when a number of cores are necessary they frequently require to be assembled and secured before lowering into the mould. Thus the core for the regulating valve, previously referred to, is made in three parts, corresponding to those in Fig. 56. The grids in three cores should not only provide facilities for lifting, but should enable their assembly to be done with safety. A suitable type of grid for the joint surfaces of the top and bottom cores is shown in Fig. 57. The casting being of steel, it is advisable that the grid should offer little resistance to the core crushing.

Arrangement of grids and assembling of the cores is shown in Fig. 58. Loam is frequently used for cores; no ramming being necessary, it is useful when ramming would be difficult or when a shape can be wholly or partially struck up with a sweep or strickle. Thus the port and exhaust cores of a steam cylinder, like Figs. 59 and 60. are conveniently made in loam. These cores



FIGS. 57 AND 58. ARRANGEMENT OF GRIDS AND CORES

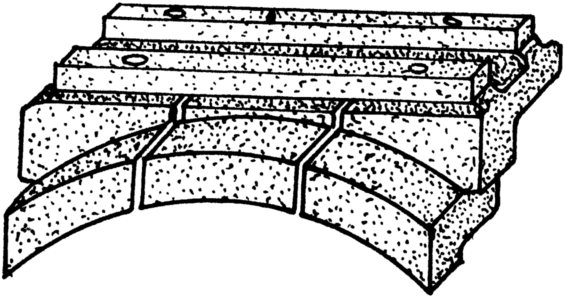


FIG. 59. PORT CORE

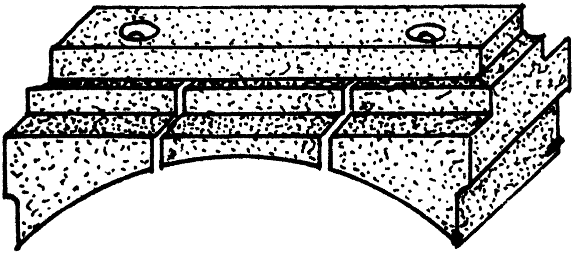


FIG. 60. EXHAUST CORE

are generally assembled on a chest plate, which forms part of the mould, as in Fig. 61. Each core carries a grid in which staples are cast by which they can be bolted to the back of the plate (see Fig. 62). Loam cores may be swept either vertically or horizontally similar to making loam patterns, but with greater care, so that they are suitably vented. A frame may be supplied, and a half-height sweep from which half cores are made, dried, and then fastened together. When one half core is made the frame must be reversed for the other half for such as that illustrated in Fig. 63.

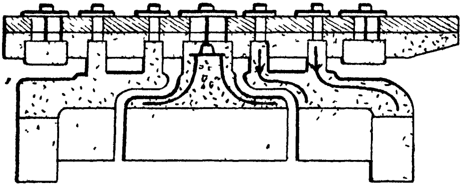


Fig. 61. Chest Plate

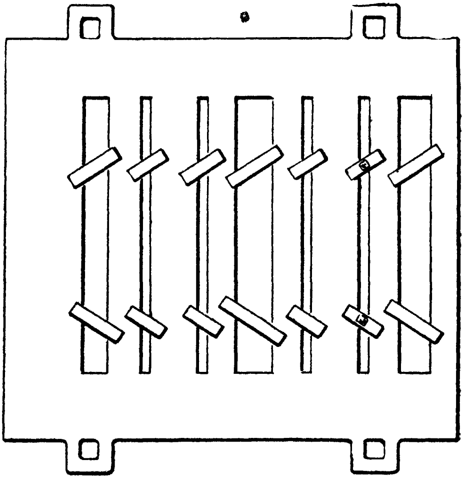


Fig. 62. Staples Bolted to Chest Plate

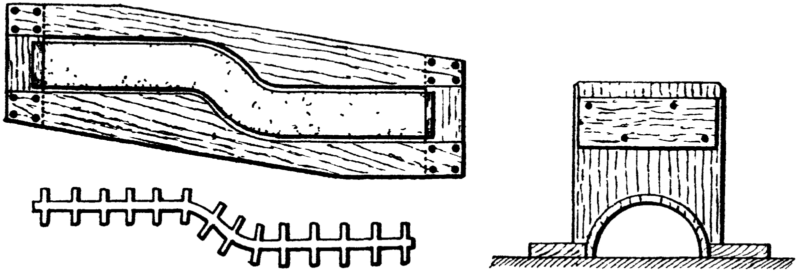


Fig. 63. Non-symmetrical Cores

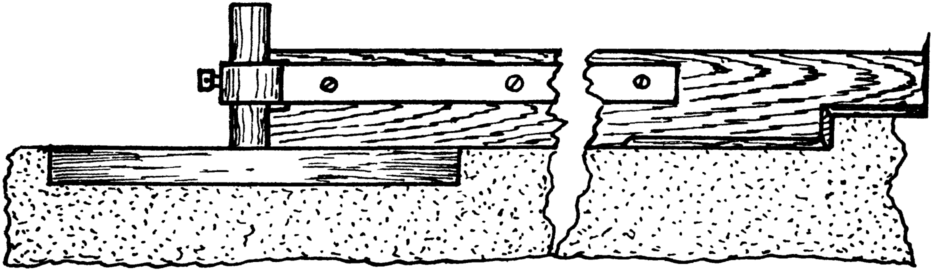


Fig. 64. Large Print and Sweep

Moulds may be made almost entirely of cores. A large sheave wheel is one instance of this kind. A large print and a sweep, as in Fig. 64, form a sand bearance to receive the cores in Fig. 65, the first of the boss cores being located on the bearance, and a row of segmental cores partly forming the rim. Mild steel arms are located when the middle part for the boss is set, enabling the alternate arms to be located. The groove cores and centre core being placed, the closing cores can be set. The cores should be weighted while sand is rammed about them preparatory to casting.

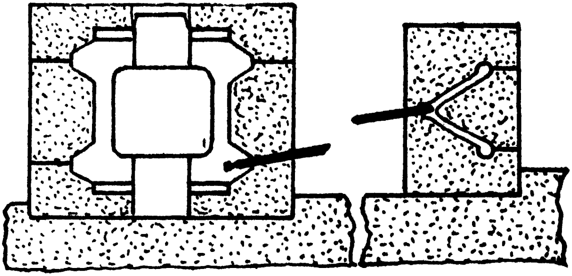


FIG. 65. SHEAVE WHEEL CORES

RUNNERS AND RISERS

One of the most important considerations for ensuring sound castings is the design of pouring basins and gates. These should be so formed that only clean metal enters the mould. In some cases it is possible that any scum entering a mould may rise with the metal and enter a judiciously placed riser, but there is no guarantee that this will happen; it is more likely to be left in the casting. There is greater need for care with iron castings as the iron is poured from the ladle spout, whereas steel ladles generally release the metal from the bottom. The thinner the metal sections and the more complicated the design the hotter the metal should be, and the greater the need for distributing it about the mould by means of runners.

The special function of the runner basin is to act as a receiver or funnel to prevent the splashing of metal by giving a larger pouring area and to maintain a head of metal from which the downgate is supplied. It also acts as a distribution chamber when many downgates connect it with the mould. A common form of basin for large work is shown in Fig. 66. In this case stoppers prevent the metal entering the gates until the basin contains a considerable quantity of metal; thus dross rises to the surface and, when the stoppers are lifted, clean metal enters the mould. When the downgate is left open when pouring, the basin should be formed to trap dross that may pass from the ladle. A skimming basin like Fig. 67 carries a slab core at *A* which allows clean metal to pass under it. Ordinary pouring basins should be designed to prevent the first splash of metal entering the mould; thus, in Fig. 68, the first metal is likely to be forced to *A* by subsequent metal, and will gradually rise as the basin is filled. The depth of the basin should be sufficient to reduce agitation of metal and allow dross to rise. A gradient towards the downgate designed as in Fig. 69 has a similar effect, the first metal being forced to *B*.

Strainer cores introduced into the downgate are valuable in preventing dross passing. They are conical in shape, have a number of small holes passing through, and to prevent the first metal passing through they should be covered with paper. This holds long enough to have a head of metal in the basin. As an extra precaution against dross entering a mould, skimming gates may be used. A common method is to run the metal into a circular chamber at a tangent, causing the

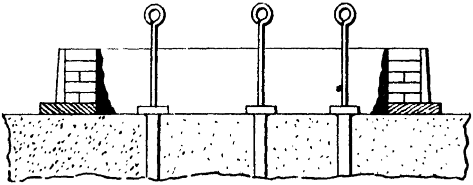


FIG. 66

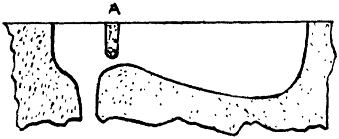


FIG. 67

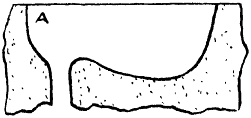


FIG. 68

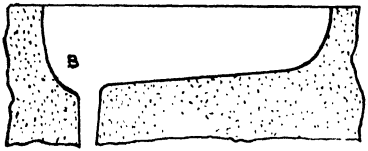


FIG. 69

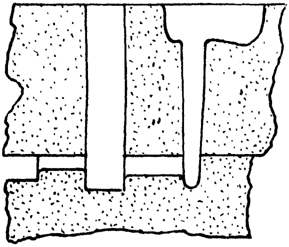


FIG. 71

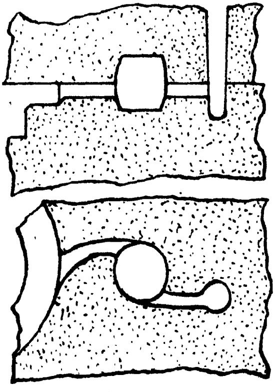


FIG. 70

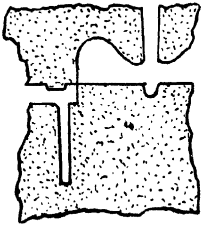


FIG. 72

DETAILS OF BASINS AND GATES.

metal to swirl and forcing dross to the centre and connecting the mould with the chamber, as shown in Fig. 70. The chamber may be extended to form a whirling riser, as in Fig. 71. Edge runners are useful for small work when the metal is very fluid. In this instance a chamber capable of holding a good body of metal just touches the mould along an edge, as in Fig. 71, and the head pressure ensures the gradual filling of the mould. Runners vary in size and shape to suit the size of casting and the metal to be cast. Cast iron, because of its greater fluidity, needs smaller runners than steel. When a wide surface is to be covered and the casting is thin, wedge gates are necessary, but all contacts with casting should be of the bottleneck type, and for thin work run from the joint spray runners are a necessity. Risers are used primarily as feeders, and are placed in the top parts of moulds to make up for shrinkage on thicker parts of the casting. They also allow gases to escape readily, reducing the pressure from the top of the metal as it rises in the mould. When risers are necessary in green-sand moulds it is advisable to cover them and maintain some gas pressure in the mould. In some castings, particularly cylindrical castings, that require to be sound, special feeder heads are cast on. They vary in shape somewhat, but should be thick enough to remain fluid longer than the casting. A common form is illustrated in Fig. 73. The use of risers of ample dimensions is very important on steel castings to minimize the effect of high shrinkage.

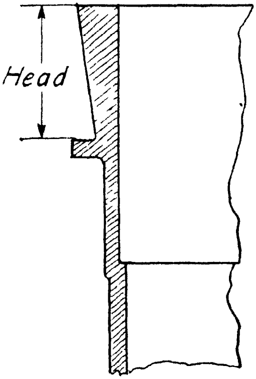


FIG. 73. FEEDER

CONTRACTION DIFFICULTIES

Of the many difficulties associated with the production of sound castings, the shrinkage and contraction of the metal is not the least troublesome. Even though castings may be designed to simplify their production (and this is not always the case) many contraction difficulties remain to be counteracted by the moulder.

Changes in metal thicknesses cannot be avoided, but the differences in the rate of cooling due to varying thickness create strains in the casting, which may cause fracture or seriously interfere with its strength. When changes in thickness are necessary they should be made gradual rather than abrupt, in order that the variation in the rate of cooling will be gradual. Any abrupt change is a source of weakness, particularly to a steel casting. It is a common practice to assist the cooling of thicker parts by introducing metal chills in the mould. The chills extract the heat from the metal quicker than the sand forming the mould; consequently, with their judicious use more regular cooling will result. These metal chills are located against the pattern preparatory to ramming the mould. Their use in green-sand moulding is attended with difficulties from condensation; they should be warmed just before casting, to reduce the possibility of the casting being blown. Steel moulders' nails are effectively used, not only to stiffen the sand against the cutting action of the metal, but for chilling purposes. They are frequently introduced into a mould so that they will pass through the metal, cooling the metal surrounding them more rapidly, and making the rate coincide with thinner metal adjacent to it.

The mould and cores must have the requisite strength to withstand the wash and pressure of the fluid metal, and yet be weak enough to crush under its strain when contracting. Grids or irons that are used to strengthen moulds or cores are likely to interfere with the contraction of castings. To reduce this probability the ends of the grids should be well clear of the face and, for large work in steel, not less than 2 in. clear, and, in many cases, wrought iron dabbers or prods are more profitable to use in the grids, as they are less rigid.

The grids in cores that are almost surrounded with metal are not accessible, for easing must be constructed so that only slight resistance to crushing is offered. Unbonded silica sand may be used in places to weaken an otherwise strong core, and wood blocks may be rammed up in a mould, and on stripping, their impressions filled with unbonded sand.

Easing the casting just after the metal has solidified is a more common method of reducing contraction strains. Parts of the mould likely to offer most obstruction are loosened. A very convenient way to reduce the laboriousness of easing a casting is to ram an old chain in the sand, introducing it behind flanges as the ramming proceeds, and having the end accessible for pulling with a crane after the job has been cast. This serves to weaken parts that may give trouble. Apart from the need of weakening the formation of the mould to release the strain on a casting it is advisable, in many instances, to support projecting parts of a casting in order that the effect of the mould's resistance is reduced. This is done by introducing thin webs connecting the parts likely to be strained by the mould with the main body. They are usually about ¼ in. to ⅜ in. thick, but considerably less than the thickness of metal they connect. It is the thickness that gives these webs their special value; they solidify rapidly, and during the critical time, when the casting as a whole is contracting, they support the thicker parts to which they are connected.

Steel castings are likely to become misshapen, particularly if they are large, due to the varying rate of cooling and resistance offered by their moulds. In order to restore the alignment of such castings, they are invariably annealed. They must be supported so that their shapes will become adjusted on raising them to a high temperature in an annealing furnace. Considerable care is necessary in setting them, and the heat should be raised very slowly to enable all parts to become heated at an equal rate. The temperature should be raised to between 800° and 900° C.. and the same care is necessary in slowly reducing the temperatures to normal. Heat treatment of this kind, in addition to releasing strains in the casting, tends to break up the coarse crystalline structure of the metal, making it finer and more regular,which naturally adds to its strength and reliability.

ASSEMBLING AND CLOSING MOULDS

Metal, when cast into moulds, exerts pressure, and it is necessary to take precautions, when assembling and closing moulds, to reduce the possibility of any part being strained or moved in consequence of the pressure. The pressure of fluid metal at any level in a mould is due to the pressure of a column of metal above that level, and is known as the head. Supposing the bottom of a core or projecting part of a mould is, say, 11¼ in. below the level of the pouring basin, then the pressure tending to lift the part would be 3 lb. per sq. in. of its area if the metal is cast iron, while if steel, 3¼ lb. pressure per sq. in. would be exerted. It is convenient to base calculations on pressure per sq. in. of area, allowing 11 lb. pressure to every 3¾ in. of head in iron castings, and 3½ in. of head in steel castings.

The buoyancy of a core is equal to the difference between its weight and the weight of an equal volume of metal that it displaces, and as soon as the metal rises above the height at which the weight of displaced metal coincides with the weight of the core, a force is exerted, and this force increases in amount as the metal rises in the mould, until the core is completely covered, when the force becomes stationary.

In addition to ordinary fluid pressure, it is necessary to take into account the momentum of the metal. During the time the mould is being filled the metal is moving, and this movement is stopped suddenly in contact with projecting parts of the mould or cover. It is this force which frequently causes parts of the mould to be moved or the cover to be lifted. It is difficult to estimate the momentum, and much depends upon the speed of casting. Quick running with hot metal may give a momentum pressure more than the head pressure. The head pressure may be calculated, but that due to momentum can only be estimated, and judgment, as well as experience, is essential in counteracting the forces. It is advisable to calculate the head pressure and add sufficient for that due to momentum, according to the conditions of the mould and metal and the speed of pouring, remembering always that it is better to add too much than too little. Knowing the approximate force tending to lift, precautions can be taken to counteract it.

The side pressure in sand moulds is counteracted by the resistance of the box sides, provided they are strong enough. Box-bars act as tie bars and give considerable support. Much work is cast in the floor, when the side and bottom pressures are counteracted, and this is a satisfactory method of dealing with loam work. When loam work is cast above the floor the gaggers, on lifting or building plates, may be secured with chains, or an iron sheath may surround the mould in which floor sand is tightly rammed. Various methods are adopted to resist lifting pressure. With small work, clamps securing the top handles or lugs will suffice.

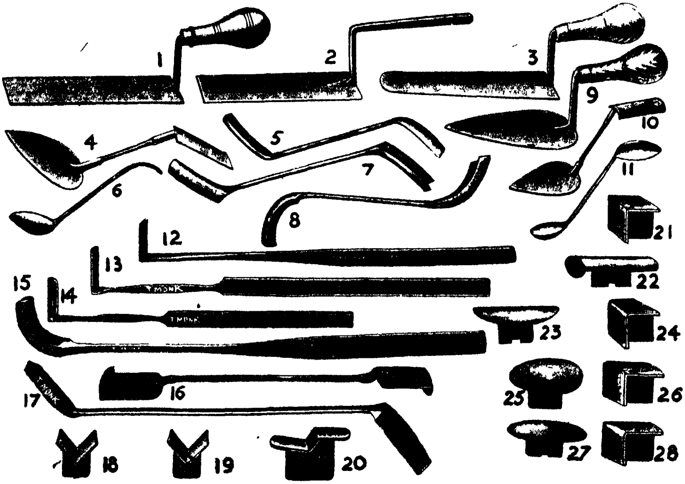


FIG. 74. SOME MOULDER'S HAND TOOLS

1. English trowel
2. Scotch trowel
3. Taper trowel
4. Heart and square trowel
5. Fluted bead
6. Dog tail tool
7. Straight bead
8. Circular bead
9. Long heart trowel
10. Gait knife
11. Spoon tool
12. English cleaner
13. Scotch cleaner
14. Scotch club cleaner
15. Flange cleaner
16. Boss tool
17. Girder tool
18. Square corner joint smoother
19. Round corner joint smoother
20. Check edge smoother
21. Square corner smoother
22. Safe end pipe smoother
23. Oval pipe smoother
24. Round edge corner smoother
25. Bacca box smoother
26. Square edge flange smoother
27. Egg smoother
28. Round edge flange smoother

Cotters may be used through the box pins or hooks fixed to the cope secured to pins in the drag. With medium and large-sized work it is not always sufficient to depend on clamps over joint flanges or between top and bottom flanges of boxes. Slotted cast iron beams resting on top of moulds that are capable of being bolted to the bottom part give greater security. It is not good practice to depend entirely upon weights applied to the top of the mould. It is better to use weights to supplement resistance when the mould has been securely clamped.

MOULDING AND CORE-MAKING MACHINES

Moulding machines are essential in repetition foundries, and have also a considerable range of usefulness in jobbing foundries. They can be classified according to the method of ramming, the method of pattern drawing, and the motive power required. They may be hand-operated, while electric, hydraulic, and pneumatic machines have each their own advantages. It will be sufficient to describe briefly some generally-used types of machines.

The simplest type of hand moulding machine is the hand ram turnover table moulding machine (Fig. 75). By means of a small lever the box carrying the carriage is raised until flush with the under side of the rammed mould, and after releasing the cotter pins the mould is lowered away. As the turnover table is free on the trunnions, the under side of the mould can bed itself on to the mould carriage, and then the turnover table is locked by means of a locking stud on each trunnion. This type of machine may be fitted with mechanical gear for turning the table and raising the mould carriage, or it may have a presser head—hand operated—for ramming the sand. Some moulding machines simply draw the pattern from the mould or the mould from the pattern. On one type of hand machine the moulding box—or core-box—is carried on a special roll-over table, set to roll on its own centre of gravity, hence the weight of the mould or core above the centre helps to carry the load over. After each ramming, the mould or core is clamped , the clamps can be shifted to any position along the length of the table, and hence will deal with boxes of various lengths. A hand lever operates the rolling over of the table, thus bringing the box to the under side. The mould-receiving table is then raised by means of the foot treadle, to carry the mould or core, and the clamps released. The drawing of the box from the pattern, or the core from the core-box, is accurately controlled by a foot treadle and hand lever working together, which gradually lower the mould-receiving table.

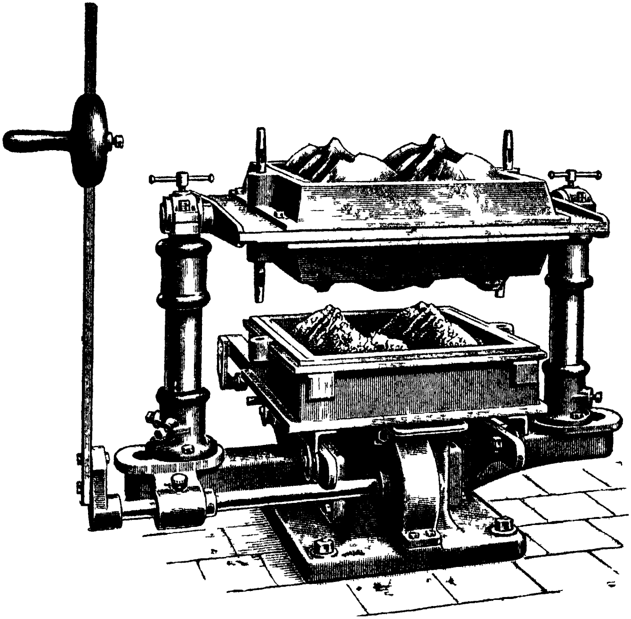
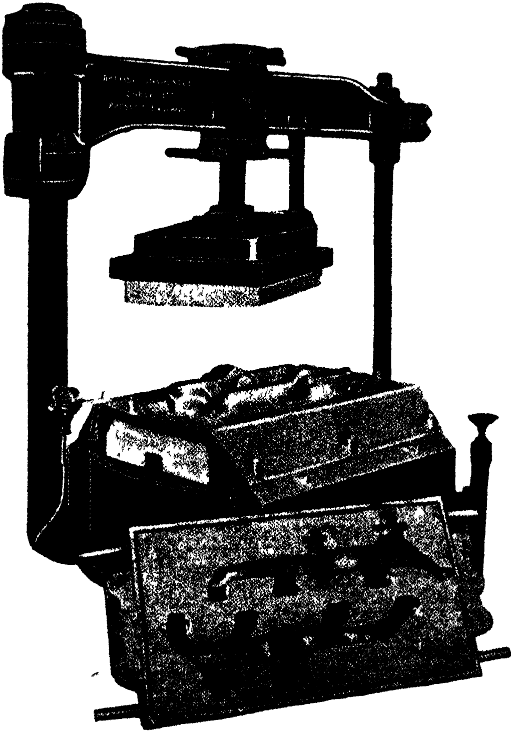


FIG. 75. HAND MOULDING MACHINE

Electrically-operated moulding machines are available in several types, the simplest of which is the squeeze strip machine shown in Fig. 76. This machine is suitable for single- and double-sided pattern plate work and can be arranged to permit the use of various shaped moulding boxes. Standard machines are made with a 3½ in. or 6 in. strip, but machines are available with a stripping height of 10 in.



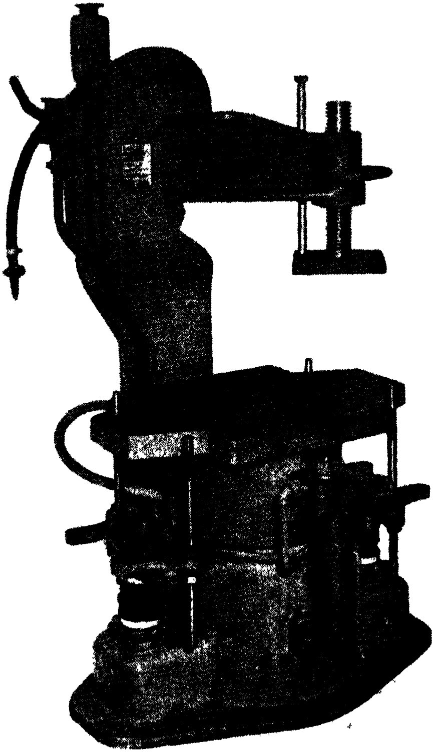
(*British Insulated Cables, Ltd*)

FIG. 76. ELECTRICALLY-OPERATED SQUEEZE STRIP MOULDING MACHINE

In operation the moulding box is placed over the pattern plate and the pressure head of the machine adjusted to a suitable level; a loose sand frame is placed over the moulding box and sand supplied to loose sand frame level. With the cross arm carrying the pressure head in position, depression of the squeeze button will cause the stripping frame with moulding box to rise and effect the squeezing operation. By releasing the squeeze button the machine table will return to its former position, leaving the moulding box on the stripping frame. During this return stroke the mould is vibrated to effect a perfect strip from the pattern plate. The movement of the table on the return stroke is controlled by an oil dash-pot and adjustable needle valve by which any desired stripping speed is obtained.

In the latest types of electrically-operated moulding machines the stripping frame rods are also fitted with pistons which work in oil dash-pots, and these being interconnected are synchronized in operation and give perfect balance; this ensures as nearly as possible a perfect strip. By adopting this method a more rapid stripping speed can be maintained than by the mechanical method. Electric machines are designed for single- and double-sided pattern plates and besides being highly efficient and serviceable, they are economical in use since power is consumed only when they are being operated, each machine being a separate unit.

Press machines have, for many years, been operated by pneumatic and hydraulic pressure and are not likely to be readily displaced for making moulds. They are both rapid in operation and practically free from vibration. Compressed air is used to a great extent for machines designed for small work, while both large and small machines are operated by hydraulic pressure. The latter results in greater pressure being more easily obtained, is more effective, especially over large surfaces, and gives better control. A plain press machine operated by compressed air is shown in Fig. 77. It is equipped with a pattern-drawing device which is a useful feature. As the table lifts on the pressure stroke, the draw pins rise with it. Immediately the pressure is released, the table and pattern descend, but the draw pins remain locked, and the pattern is thereby drawn



(British Moulding Machine Co. Ltd.)

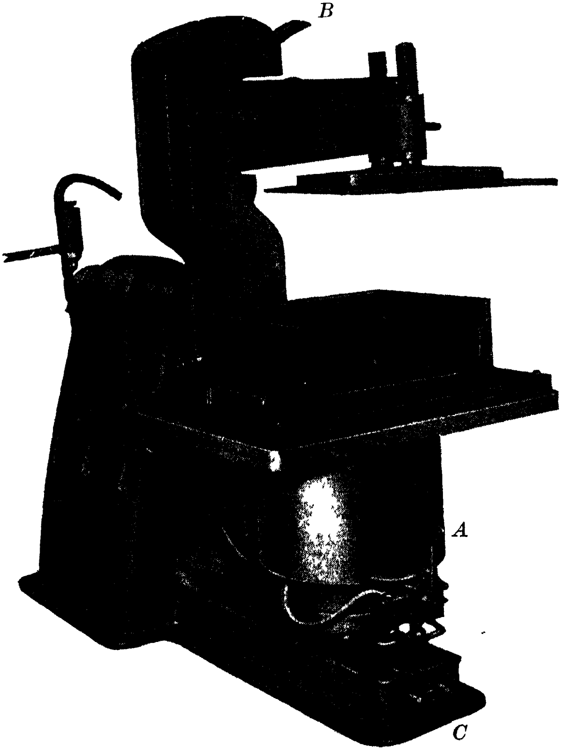
FIG. 77. PLAIN SQUEEZE MOULDING MACHINE

from the mould. Machines are also available, operated by either motive power, which are equipped with turnover devices to permit pattern-drawing in the normal direction.

With all press or squeeze machines, whether hand or power operated, a loose frame is used on top of the moulding box, as an extension piece, to hold the quantity of sand to be pressed and into which the press head will enter as pressure is applied. In consolidating the sand in this way the pressure is maintained long enough, at the end of the stroke, to permit air to escape. This makes the matrix firmer.

The jolt-ram machine impacts the sand in a rapid and uniform manner on the pattern, without the least damage to the latter. This action is due to the repeated bumping of the jolter table, carrying the pattern or pattern plate on the anvil block, and the consequent impacting of the sand in the box. In the case of any type of squeezer or press machine working on deep work, the ramming of the sand is only partial, and is generally softest nearest the pattern, just where the ramming should be hardest, so as to resist the pressure exerted by the molten metal. In jolt-rammed moulds the sand is rammed hardest nearest the pattern, so facilitating easy and uniform escape of gases. These machines may be obtained for pneumatic, hydraulic, or electric operation. The action is not one of " tossing " as regards the moulding box, pattern, or sand, but results in the very rapid packing of the sand on the pattern within the moulding box. In other words, the sand is not " jarred " or " vibrated," but definitely settles down in positive vertical stream lines all over the pattern. The blow may be made hard or soft, as desired by adjusting the exhaust valve.

It is considered by some foundrymen that pneumatic pressure provides the advantage of obtaining high pressure with a reasonable diameter of cylinder, and that the incompressibility of a hydraulic medium permits of a very sweet and steady jolt, and at the same time quick movement of the piston for pattern drawing.



(*British Moulding Machine Co. Ltd.*)

FIG. 78. COMBINED JOLT AND SQUEEZE MOULDING MACHINE

In some machines the advantages of the press and jolter are combined, as in Fig. 78, which shows a jolt-squeeze turnover machine with independent jolter, with pneumatic pattern drawing facilities. The complete cycle of operations with this machine consists in moving lever *A* to the left, which starts the jolt; the arm is then swung into position and lever *B* depressed, which effects the squeeze and stops the jolt. Lever *C* is then moved to the right, which turns the machine over. By moving levers *A* and *B* the pattern is withdrawn and the machine returned to the jolt position by moving lever *C* to its original position.

One type of machine rams the two parts of the mould simultaneously, draws the pattern, closes the box, and eventually pushes the mould completely through the box, permitting the casting to be poured without boxes. As there are no boxes, the pouring of the mould must be done " on the flat." The production is considerable, and outputs of 350 to 400 moulds in eight hours can be obtained with one machine and two operators. The manufacture of pattern plates for such machines is very simple and rapid. The employment of an electric or compressed air vibrator facilitates pattern drawing, and a blowing-off nozzle to clean plates and moulds means saving of time. and, consequently, speed in production.

The sand-slinging machine is different from all other types. The principle on which it works is that of a centrifugal blower, with the exception that air has no part in it. The sand is delivered to a revolving head, which revolves at high speed, throwing the sand into the mould in the form of an almost invisible spray. This can be so regulated as to ram the mould to any degree of hardness required. The machines are built in a number of sizes and in four distinct types—the stationary, portable, tractor, and locomotive. With the stationary type, the work is brought to the machine, while with the portable type, the machine is taken to the work by hoisting it up with the crane and delivering it to the required location. The locomotive type, as its name implies, is self-propelling, and can be run on tracks or otherwise to any place where required, while the tractor is specially adapted to regular runs of work in speciality shops.

The Beardsley-Piper sand-slinger cuts and mixes the sand on the floor, conveys it to a riddle or sieve, and then, by another form of conveyor, to an impeller, by which it is thrown vertically into the mould. The control is easy of access and the machine is very flexible with a wide radius of action. It is capable of dealing with moulding sand and ramming it at the rate of half a ton a minute, and no special patterns or box equipment are necessary.

Various kinds of machines are designed to cope with special types of work or when the number of castings of a particular design is sufficient to make the use of a machine specially designed for producing the moulds an economical proposition. A typical example of the former are gear wheel moulding machines, such as the Whittaker machine or the machine made by Messrs. Buckley & Taylor, Ltd. With these machines the moulds are made by hand, the machine carrying a sectional pattern of the teeth, and, by an arrangement of gearing capable of being varied to suit the diameter of gear and number of teeth required, the moulds for gear wheels up to a very large size are readily made. In addition to moulds for spur and bevel gears, double helical teeth are also readily moulded, and accuracy is assured as far as the operations of the machine are concerned.

CORE MACHINES

The most common form of core-making machine is that used for parallel cores of any sectional shape.

There are two types of machines—the rotary or conveyor, and the plunger. The former is used solely for parallel cores, and although any sectional shapes can be made according to the dies used, they are usually circular.

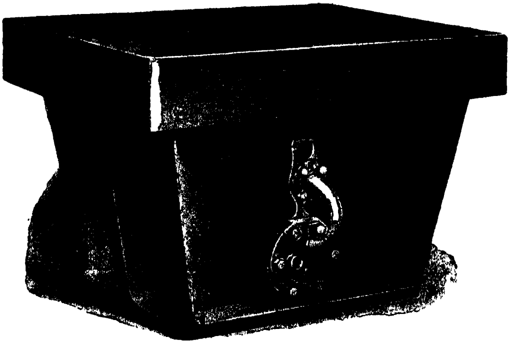
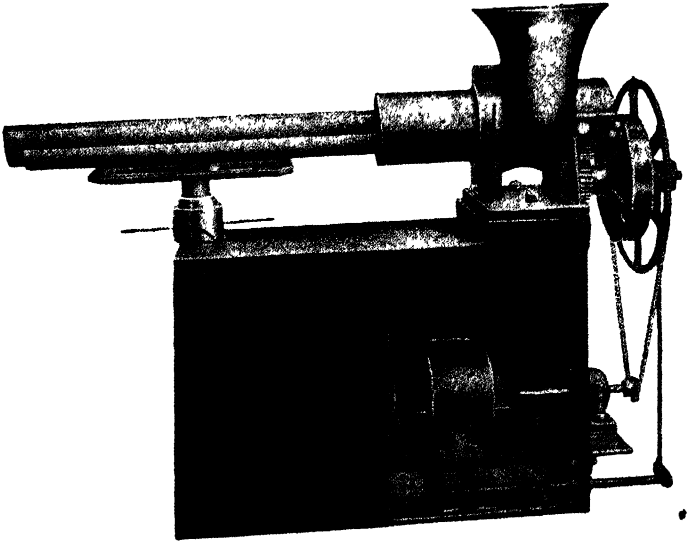


FIG. 79. 8 IN. CYLINDER JOLTER (JACKMAN)
Table, 30 in. × 42 in. Capacity, 2500 lb.

This type of machine works on the same principle a the ordinary mincing or sausage machine, sand being fed into the hopper to a worm or conveyor, which, on being rotated, forces the sand through a die and produces a core corresponding in sectional shape to the die through which it passes. The conveyor may either be operated by hand or by mechanical power, and cores ranging in diameter from $\frac{3}{4}$ in. to 6 in. are readily produced up to about 2 ft. 6 in. long. Special core plates are used to support the cores as they come through the die, and upon which they are dried. An oil sand is usually used on this kind of machine, although flour may be added to give greater green strength to the core, and so reduce the possibility of it collapsing as it is being pushed along the plate. Vents are formed in the cores as they pass the dies, and they vary according to the diameter of the cores. A typical example of this core-making machine is shown in Fig. 80. It is chain driven by means of a 1 h.p. motor.

The plunger type of machine is not confined to the making of parallel cores, but it can be used for shaped cores which can be stripped from their dies or core-boxes in a vertical direction (Fig. 81). This, however, necessitates loose pieces in the dies, and makes their construction more involved, excepting for the simplest of irregular shaped cores. In this type of machine the die is fixed to a table and over a plunger of the same sectional shape as the bottom of the die. Sand is rammed in the die by hand, and then vented when the core is stripped by means of the plunger. The plunger



(*The Fordath Engineering Co, Ltd*)

FIG. 80. MULTIPLE ROTARY CORE-MAKING MACHINE

may be operated by a direct lever arrangement or by rack and pinion, according to the type of machine used, and the sizes of cores vary from $\frac{3}{4}$ in. to 6 in. diameter, and any length up to 9 in. Oil-bonded core sands are not so suitable for cores produced on this machine, unless they have other bonds in their composition which increase the green strength of the sand, because they must be handled when they have been stripped from the die or core-box.

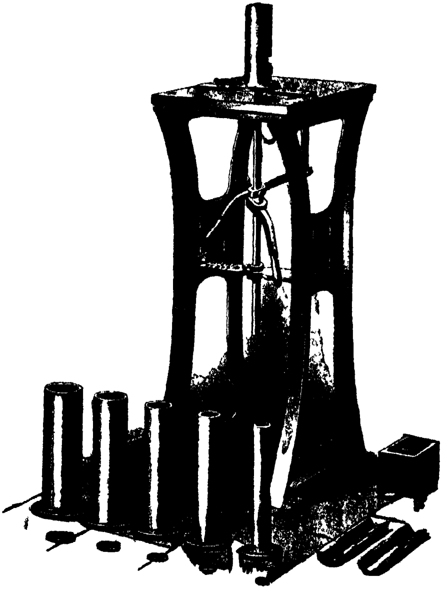
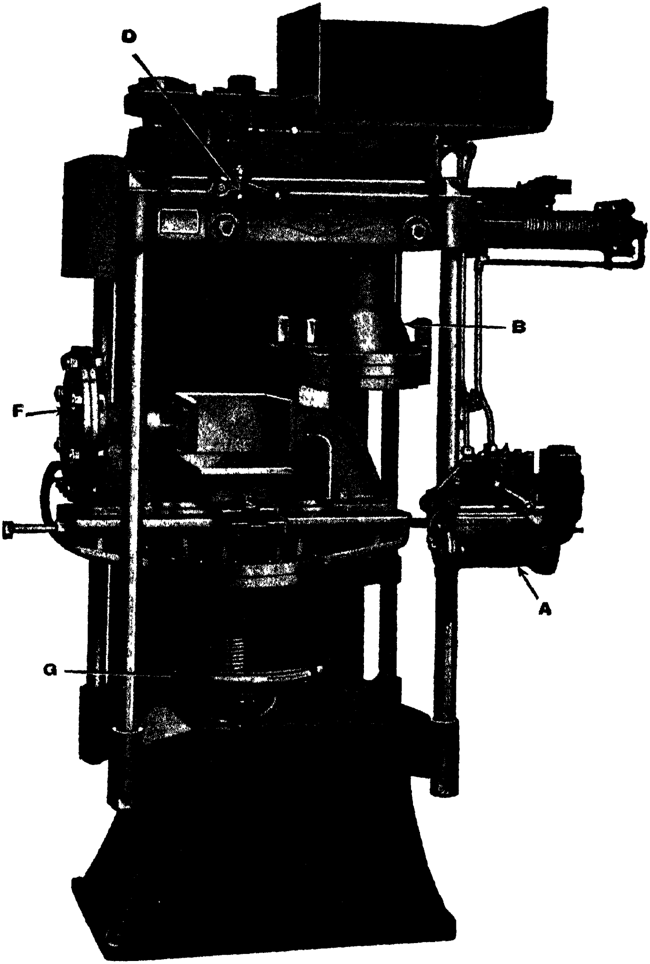


FIG. 81. PLUNGER TYPE MACHINE USED FOR SHAPED CORES

Blowing sand into core-boxes by means of compressed air is a more recent development in core-making and is proving very successful. Core-blowing machines for this purpose have become increasingly



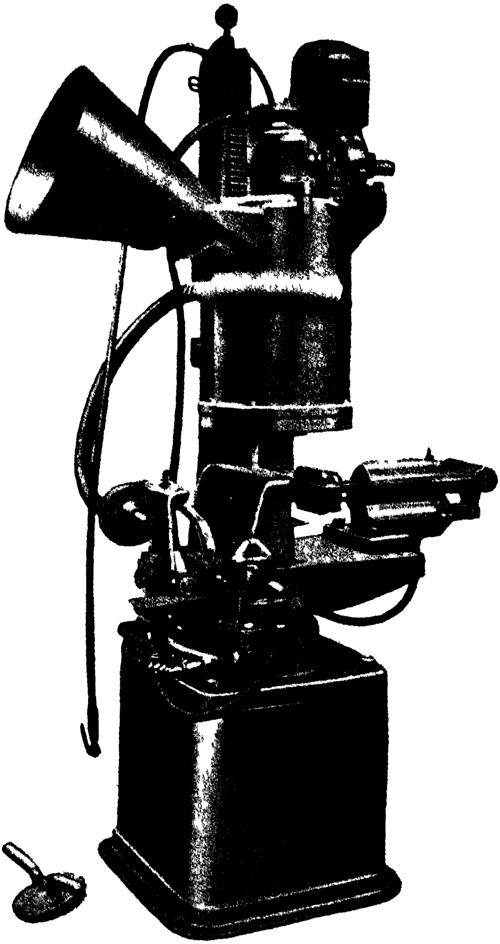
(*J. W. Jackman & Co., Ltd.*)

FIG. 82. OSBORN CORE-BLOWING MACHINE

used in recent years and, in many repetition core-shops, are regarded as indispensable. They are much more flexible than the plunger type of machine which they are displacing. They are applied to the production of irregular shaped cores which formerly could only be produced by hand. A machine of this type is shown in Fig. 82, with which it is only necessary to locate the core-box on the machine table, operate a single lever on the control valve box, and automatically the core-box is clamped to the table, the sand container moves over the core-box, sand is blown into the box, the clamps are released and the sand container returns to receive a further supply of core sand from the storage hopper.

Another machine of this type is shown in Fig. 83. It is fitted with base, motor driven sand feed, and automatic compressed air horizontal clamp. It is shown with the sand container cover removed and a funnel fitted for recharging. The container has a capacity for 90 lb. of sand. With the sand container full, air at a pressure of 85–100 lb. per sq. in. enters the container and forces sand and air through a small nozzle at the base of the container. The core-box is clamped to the table below the container with its opening opposite to the blowing nozzle, and then, by operating lever mechanism, sand is blown into the core-box automatically. These machines are very efficient and the cores produced are uniform in density and accurate in shape; they can be produced with great speed.

In addition to the foregoing many plain jolting machines are used for ramming cores and in some cases turnover devices are fitted to function on similar principles to moulding machines. Many of the plain jolters are capable of ramming very large cores, taking core-boxes of very large size.



(*The Constructional Engineering Co., Ltd.*)

FIG. 83. THE "TITAN" UNIVERSAL CORE-MAKING MACHINE

sand blasting is kept up, the difference being that the water carries the abrasive and there is a complete absence of dust. This system has been developed in the United States and originally was restricted to heavy castings, but is now being applied to small engineering castings.

The most recent development in connection with dressing castings is the evolution of a type of machine using centrifugal force to impart to the abrasive the energy necessary for removing the sand or scale. In this class are the Wheelabrator and Sand Wizard, the difference between the two machines being in the design of the impeller head; in one case it is rather like the impeller of a centrifugal pump and in the other case two blades rotate to throw the abrasive.

The airless Wheelabrator is a comparatively recent development; the apparatus consists of a motor, V-belt drive, shaft bearing, abrasive feed, and the wheel which throws the abrasive. The abrasive suited to the work is fed by the gravity into the wheel, which rotates at high speed, and then by centrifugal force it is thrown from the wheel upon the work being cleaned or surfaced. A device built into the wheel controls the direction of the abrasive, which is thrown into the work. One machine of this type has an operating capacity of 17½ cub. ft. and can deal with large production or the handling of pieces of bulk or weight. For a unit to deal with delicate and intricate casting a conveyor is designed to bring all the faces of the articles under the action of the stream of abrasive with a minimum tumbling action, and, therefore, the most fragile pieces can be cleaned without breaking. The speed of the conveyor in conjunction with the correct grade of the abrasive can be arranged to produce any desired surface and ferrous and non-ferrous castings can consequently be treated.

There are multi-table types of the Wheelabrator in which the work to be cleaned is carried through the cabinet on a number of tables. These tables rotate as they pass through the blasting zone in order to expose all surfaces to the abrasive blast. There may be one or more units according to the shape of the work. The opposing abrasive stream or streams completely bombard the work with machine-gun effectiveness. The speed of the main spider and of the tables mounted thereon are adjustable, and table operations are controlled from one main push button station. The smallest machine of the type has a loading capacity of 2 cub. ft. and large quantities of small castings can be cleaned in a few minutes, while a rubber conveyor eliminates breakage of fragile castings.

SECTION VII

BRASS FOUNDING

BY

J. McLACHLAN

AND

CHAS. A. OTTO

SECTION VII

BRASS FOUNDING

INTRODUCTION

THERE are no fundamental differences between ferrous and non-ferrous foundry practice, and there is no reason why an iron moulder should not, in a short time, become a successful brass moulder, and vice versa. Brass moulders are often very successful in the manufacture of light and delicate iron castings, while iron moulders may be very successful with certain classes of large and heavy brass castings.

As loam, dry, and green sand are used for brass moulds, the lay-out of a brass foundry is similar to an iron foundry. The chief difference is, perhaps, that there is generally a larger proportion of small work, and thus more moulds are made on benches or in " tubs "—troughs—but, while there is no difference in the actual practice, there is a larger variety of metal mixtures to be dealt with. In a jobbing brass foundry especially, there may be casts of several mixtures of brass and bronze in the course of a day to comply with customers' specifications. Thus the metallurgical side of brass foundry practice is complex.

The wide range of mixtures of varying pouring temperatures necessitates considerable experience and judgment to produce sound castings. The castings manufactured may be classified, broadly, under brasses, bronzes, and aluminium, and each metal requires special consideration and treatment. Non-ferrous metals are expensive, and are not used for large work unless the special properties they possess make it desirable to satisfy special conditions of service.

Many non-ferrous alloys chill and solidify very quickly ; they have not the fluidity associated with cast iron, and it is therefore necessary to increase the area of entry to the mould, otherwise the metal may not fill it, and, even if it does so, may cause parts to become so cold that they may fail to unite.

There are certain differences in regard to finishing moulds for brass compared with iron, and, generally, finer sand and different facings are used. The tackle in a brass foundry is of a lighter kind than in either iron or steel foundries, and there is also much greater variety in the types of furnaces used.

MELTING EQUIPMENT AND APPLIANCES

In small foundries, where only a few men are employed, the furnace or furnaces are often of the simplest kind, and melting is not always given the attention it ought to have. The coke-burning crucible furnace is most generally used, and it is, when properly used, comparatively economical. There are pit furnaces, tilting furnaces, lift-out furnaces, roller furnaces, reverberatory furnaces, and other types of brass furnaces, not all of which are crucible furnaces, although crucibles are used. The fuel employed may be coke, coal, gas, oil, or electricity. There is not agreement among either metallurgists or foundrymen as to the best type of non-ferrous melting furnace, and it will never be possible to design a furnace that will conform to requirements under all conditions and circumstances.

The various alloys are prepared in the first place from the virgin metals and cast in ingot moulds. It is important to remember that those metals that have the highest melting points should be melted first, and other metals introduced in the order of their melting temperatures. The additions to form the alloy should be made gradually to reduce the chilling action on the base metal, and, when the quantity to be added to the base metal is considerable, it is better to introduce only a part in this way, the remainder being melted separately and added in a molten state. The mixture should be thoroughly stirred before pouring into the ingot moulds and at the time of adding the pieces of metal. Allowance should be made for volatilization and oxidization when adding metal. Zinc, for instance, added to copper, is reduced about 10 per cent by volatilization, and tin oxidizes when introduced into copper, although phosphorus assists in counteracting this tendency. Copper should be melted under charcoal to prevent oxygen being absorbed. In making up mixtures for actual casting, the analysis of both ingots and scrap should be known, and it is always necessary to make allowance for loss of zinc that may be in the mixture.

THE ELECTRIC FURNACE

Electric furnaces have been installed in very few brass foundries in this country, one reason being the relatively high operating costs. With cheaper power, no doubt, greater use would be made of electric furnaces, because they offer the advantage of cleanliness from foul gases, and offer better facilities for melting in a neutral or reducing atmosphere. An important recommendation of the electric furnace is the more accurate control of melting that is possible.

With non-ferrous metals the electric resistance is usually low, too low indeed to obtain the best results from an induction furnace. One type of electric furnace, however, is heated by the transference of heat from a resistance material through which the current passes. From the resistance forming the retainer the heat is distributed uniformly. Some of these furnaces are crucible furnaces, the crucible forming the resistance, although they are usually insulated to protect the metal.

Electric furnaces are more frequently used for non-ferrous alloys that have to be rolled, than for the production of castings required as such. A cleaner alloy is produced, and this compensates for the additional cost of melting when it is to be rolled. Arc furnaces are more generally used for this purpose, although the arcs are not usually in direct contact with the metal. There is considerable oxidization when the zinc content exceeds 20 per cent. The upper walls of the furnace become too hot, and, invariably, rocking or other movement is resorted to, so that the metal will cool them.

GAS-FIRED FURNACES

Gas has been increasingly used in both ferrous and non-ferrous foundries in recent years. One use is for drying moulds and heating core ovens, and another is for melting non-ferrous metals. The use of gas in various forms as a fuel for crucible furnaces has the advantage of cleanliness not only in the working of the furnace, but in the melting, and it has a considerable range of adaptability whether the melting is infrequent or continuous. Gas is used in the majority of the types of furnaces, but more particularly with the lift-out and tilting types. In lift-out furnaces, crucibles may be arranged in series in one chamber, and the heat supplied from one or two burners, or the chamber may be circular in shape, similar to that used for solid fuel, the space between the crucible and the chamber being reduced for economical reasons.

The burner and the mixture and gas introduced are important factors in the economic working of gas-fired furnaces. The flame should not be directed against the crucible, or its life will be considerably reduced. The surface should be so constructed that the flame enters tangential to the circular chamber, when it can circulate about the crucible and provide regular heat from the bottom upwards. The kind of burner used depends in some degree upon the gas. As burners carbonize to some extent in use, they must be examined periodically and cleaned. A wide range of adjustment is necessary because, even in the case of town's gas, the heating value, as well as the pressure, changes from time to time. This makes it necessary to modify the mixture of air and gas to obtain the most efficient flame, and, at the same time, the right proportions of air and gas must be watched very closely in order to protect the crucible, and more especially so if a graphite crucible is being used in the furnace. An excess of gas reduces the temperature of the flame and therefore the efficiency of the furnace, but, on the other hand, too much air in proportion to gas reduces the life of the crucible.

An important factor in favour of gas furnaces—and oil furnaces also—is that, as no stoking is required, with a consequent loss of heat, the metal can be more quickly melted than with solid fuels. In comparing different types of furnaces, the condition of the metal and the loss experienced in melting must be taken into consideration ; the melting efficiency has an important bearing on its relative value, but it must be admitted that comparison is difficult, because much depends upon the amount of superheat that may be imparted to the metal before pouring, and the number of continuous heats that may be made.

Aluminium may be melted in the same furnaces as brass and bronze, although it is possible to obtain furnaces that have been specially designed for soft metals, including aluminium. Figs. 1 and 2 illustrate one such furnace with tunnel type burners arranged as indicated at Fig. 2. This furnace has what is called an air-gas proportioner of either high- or low-pressure types, as available facilities with regard to air supply may determine; it mixes the gas and air in the correct proportions for proper combustion without need for adjustment by the operator. This makes the maintenance of a non-oxidizing atmosphere surrounding the metal positive and automatic. One valve controls the temperature, and a thermostat can be applied with ease and with the certainty of good results. The hot gases from the burners enter tangentially to the furnace lining, and envelop the entire surface with a rapid swirling motion.

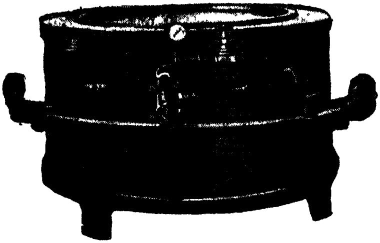

(British Furnaces Ltd.)

FIG. 1. AUTOMATIC CIRCULAR GAS FURNACE FOR SOFT METALS

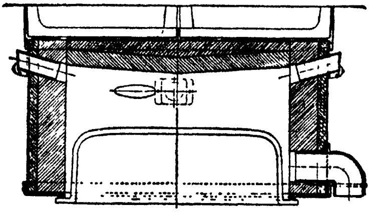


FIG. 2. SECTIONAL VIEW OF FURNACE SHOWN IN FIG. 1

OIL-BURNING FURNACES

Oil-burning furnaces form an important class for non-ferrous melting. The advantages of such furnaces are similar to those consuming gas. Both types of furnaces have this in common, by comparison with solid fuel furnaces, that there is no waste of fuel, as it is only being consumed when actually required. Immediately the metal is in a condition to pour, the consumption of fuel is stopped; other advantageous points are that the output is greater, labour charges are less because little time is involved in attending to them, there is better temperature control which tends to produce better metal, and, as fumes are reduced to a minimum, the metal is not contaminated to the same extent as when coke is used, and, finally, floor space is economized. On the other hand, efficient working depends on the skill of the operator perhaps even more than with the coke furnace, and both gas and oil furnaces can become really costly melting devices.

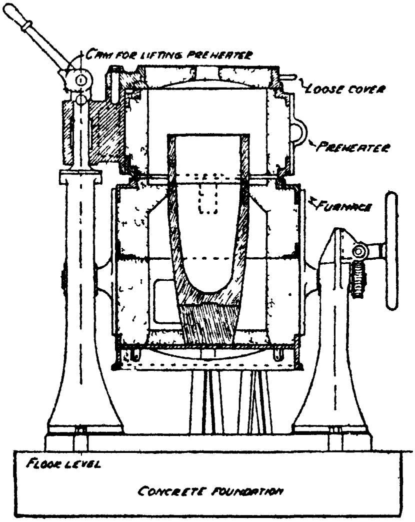


Fig. 3. Tilting Furnace Suitable for Oil or Gas

Oil is used for tilting, stationary, and lift-out furnaces, and also rotary furnaces that do not involve the use of crucibles. In reverberatory furnaces also it is sometimes used. The oil is heavy oil under pressure to ensure a steady supply, and air, either under high or low pressure, may be introduced according to the type of burner used. One point in its favour by comparison with gas is that the cutting action on the crucible is not so pronounced. At Fig. 3 is shown a tilting furnace that is suitable for either oil or gas.

Rotary furnaces are not much used in this country. They are cylindrical drums supported horizontally so that they can be rotated, and they are lined with refractory material against which the metal comes into direct contact. The source of heat in these furnaces is gas or oil or electricity, as with the crucible tilting or stationary furnaces. The metal is charged in the furnace instead of the crucible, and when melted the furnace is rotated and tapped from the spout, the moulds being either transported to the furnace for casting, or the metal carried in prepared ladles or crucibles to the mould. The flame from the burner, or burners, comes in direct contact with the metal, and even greater care is necessary to ensure a correct combination of air and fuel than with the crucible types of furnaces.

COKE FURNACES

We now come to the most common type of furnaces in non-ferrous foundries. The coke-fired furnace has not the superiority over other non-ferrous furnaces that the cupola has over other iron-melting furnaces. One reason for its popularity is that foundrymen have had long experience in its use, and the fuel is comparatively cheap. A coke-fired furnace of the simplest design can be installed at a very low cost. The most common type of furnace in which coke is used is the pit type, which is shown in section in Fig. 4. Pit furnaces are usually arranged in batteries as shown, in which each furnace is a separate unit connected with one main flue. The simplest type has only natural draught, but many pit furnaces have preheated air supplied to them. They are useful furnaces when the work executed in the foundry is of limited size or of a varied nature, necessitating different mixtures of metal being cast. The furnaces are generally made to accommodate 100 lb. crucibles, although special furnaces may be adjoining these with crucibles of 200 to 400 lb. capacity, and in some cases even larger.

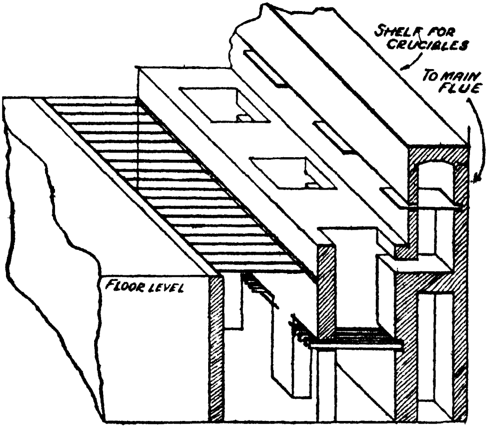


Fig. 4. Pit Type Coke-fired Furnace

With regard to constructional details, the use of dampers, for adjusting the combustion of the coke, and proper crucible supports or stands, increases the efficiency of these furnaces, and especially so when the air is controlled and preheated with the waste heat. The fire-holes may be either square or round, although round fire-holes are considered to be more economical in fuel and give a better melting ratio, but, on the other hand, square holes offer better facilities for stoking with less damage to the crucible. For round fire-holes the coke must be carefully graded, and, when the fire-holes are dimensioned to suit various sizes of crucibles as they ought to be, it is usual to make the smaller ones square and the larger ones round. Pit type furnaces are low efficiency furnaces, but this is owing to a great extent to the use of a substantial bed of coke upon which the crucible rests, and from which much of the heat is generated in the flues instead of in the fire-holes. Another point against the pit type furnace is that the crucible is dependent upon the coke surrounding it for keeping it vertical, as the bed varies with the combustion, which is not very satisfactory, resulting as it frequently does in a loss of metal.

The term lift-out furnace is sometimes also applied to a pit furnace, because the crucibles are lifted out, but it more generally refers to a furnace resembling a tilting furnace without the tilting mechanism. The furnace containing the crucible is lifted from its standard, and is used to support the crucible during the time of pouring, but the tilting furnace, on the other hand, is generally a stationary furnace, and the moulds are either transported to the furnace to be cast, or separate ladles are used to carry the metal to the mould. It follows, therefore, that the crucibles contained in these types of furnaces are not subject to wear from tongs, and their life is prolonged in consequence. They are circular, and made to accommodate a certain size of crucible with sufficient space about it to allow free combustion of the coke. Air is introduced by means of a blower or a fan, and sometimes preheated air is supplied, the preheating being done by waste heat from the melting chamber. The capacity of a crucible may be increased by an extension piece ; as the metal becomes molten and sinks, that carried in the extension piece or preheater gradually falls into the crucible, leaving the extension piece clear to be removed when the furnace is open. These furnaces may be in separate units or in batteries, but even when in batteries each is an independent unit. As compared with the ordinary pit furnace the crucibles last longer, as they are not taken from the furnace, there is control of the air, quicker melting, and larger quantities of a definite composition are more readily obtained. Their capacity ranges from 200 to 1000 lb. Another advantage is that they offer better facilities for controlling the casting temperature. The cost of installation, on the other hand, is much higher, and stoking is as necessary as with the pit furnace. As in the case of the pit type of solid fuel furnace there is a loss of heat, and a consequent slowing up of the rate of melting each time stoking has to be done, but they give a better ratio of metal to fuel.

REVERBERATORY FURNACES

Reverberatory furnaces, for which solid fuel is used in the form of coal, as well as oil, are more suitable for melting large quantities of metal which is not contaminated by the fuel. Reverberatory furnaces are sometimes referred to as air furnaces, because they used to depend upon natural draught. Such furnaces have low arched roofs that deflect the heat to the metal charged on the hearth. The fire-grate is separated from the hearth by a refractory bridge, which forms a reservoir for the fluid metal and protects it from the indirect influence of the flame. Reverberatory furnaces are very convenient when large castings have to be made requiring several tons of metal.

MIXTURES OF NON-FERROUS ALLOYS

The work in the brass foundry usually embraces all non-ferrous metals and alloys. Thus, while brass or bronze may form the major part of the work, it is not limited to these alloys, but white metal and aluminium alloys may also form part of the work done ; gradually, however, the production of aluminium castings is becoming a specialized foundry industry, due to the rapid progress being made in the use of alloys that have aluminium as their base, and their production is considered separately later in this volume. White metals have always been associated with the work in the brass foundry, but while the work done is important, it forms but a minor part.

Brass. Although this term applies more particularly to alloys of copper and zinc, it is frequently used to embrace all the alloys of copper, due, no doubt, to the fact that in ancient times the alloys that we now know as bronzes were referred to as brasses. The term is also applied to other alloys which mainly consist of copper and zinc, other metals being present in relatively small quantities. Brass is harder than copper, and, according to composition, has considerable tensile strength. Some alloys, like manganese brass, have a tensile strength approaching that of steel. Brasses varying in composition between 90 per cent copper–10 per cent zinc and 67 per cent copper–33 per cent zinc have a fine texture. The melting points are higher with increased percentages of copper ; thus a common brass consisting of 50 per cent copper and 50 per cent zinc melts at 870° C., while a brazing metal of 90 per cent copper and 10 per cent zinc melts at 1056° C. Some brasses are malleable and ductile, particularly that known as Muntz metal, consisting of 60 per cent copper and 40 per cent zinc.

The red brasses varying from 80 to 90 per cent copper are chiefly used for castings of an ornamental character, the reddish colour of the metal being increased by pickling. The ordinary red brass corresponds to quarter metal, i.e. 80 per cent copper and 20 per cent zinc, but up to 5 per cent of tin and lead may be added, at the expense of part of the zinc. In the production of low-pressure valves and fittings, and of inexpensive bearings, the lead content may be as high as 10 per cent. English brass composed of 70 per cent copper and 30 per cent zinc is used for high-class fittings, invariably small amounts of lead and iron being present. Ordinary yellow brass consisting of 66 per cent copper and 34 per cent zinc is in common use for general work that does not require much strength and is not subject to friction or corrosive action. Iron and lead are usually present in small quantities. Common yellow brass containing 50 per cent copper and 50 per cent zinc is only used for unimportant work. It is a weak brass, but is useful for cheap work not subject to strain or shock. Lead is frequently added to facilitate machining, but generally the mixture casts well and is easily machined. Muntz metal, having a composition of 60 per cent copper and 40 per cent zinc, is frequently used for general fittings, but this mixture must be watched carefully as the qualities change rapidly if the proportion is not adhered to.

A modified brass, that is very tough and is valuable in resisting the corrosive influence of sea water, has a composition that varies somewhat, a typical mixture consisting of 56·8 per cent copper, 39 per cent zinc, 2 per cent tin, 1 per cent lead, 1·2 per cent iron, with traces of phosphorus. It is known as Delta metal. Another modification, that is frequently referred to as manganese bronze, offers considerable resistance to corrosion and has great strength ; it consists of 57 per cent copper, 40 per cent zinc, 1 per cent tin, 1 per cent iron, 0·75 per cent aluminium, 0·15 per cent manganese. It is used for castings that require to be strong, and is sometimes used instead of steel. Another high tensile brass of this type contains 58·8 per cent copper, 37 per cent zinc, 0·38 per cent tin, 1·12 per cent iron, 1·1 per cent aluminium, and 1 per cent manganese, with a small percentage of lead. As cast this latter alloy has a tensile strength of about 32 tons per sq. in.

Bronze. This term is applied to alloys consisting primarily of copper and tin. This alloy is considered to be the first deliberately made and used. The effect of tin in combination with copper is to produce a harder, stronger, and more durable alloy than copper and zinc. Bronze was largely used in the making of cannon, and the term gunmetal is frequently used when referring to it. The colour, though resembling that of brass, is usually lighter, though the surface darkens, which is due to oxidization. The tensile strength of bronze is fairly constant with a tin content up to 20 per cent, but is rapidly reduced as the tin is increased beyond this point. Bronze castings required to withstand steam or hydraulic pressures are strengthened by being annealed; this increases both strength and ductility. Other elements are usually introduced in bronzes to give the mixture special qualities; thus, phosphorus, silicon, manganese, and iron, added in small proportions, have remarkable effects on alloys of copper and tin, increasing their strength, making them more malleable, and increasing resistance to corrosion. Aluminium is also used, but the proportion is greater and very little tin is present.

Probably the best known of standard bronze mixtures is Admiralty gunmetal, consisting of 88 per cent copper, 10 per cent tin, and a maximum zinc content of 2 per cent. It is used for important castings subjected to high steam pressure, such as valve chests, valves, and seatings. It is also used for hydraulic work and many kinds of machine parts. A commercial gunmetal composed of 84 per cent copper, 9 per cent tin, 6 per cent zinc, and 1 per cent lead, besides being fairly strong, is easy to cast and machines well. Bell metal, consisting of 80 per cent copper and 20 per cent tin, is frequently made for dies as well as bells, and, in exceptional cases, the tin content may be increased to 25 per cent with very small percentages of iron, lead, and zinc. Practically all compositions of bronze are strengthened by the inclusion of phosphorus, thus phosphor bronzes vary much in their composition, according to the purpose for which the casting is to be used, but a mixture consisting of 88 per cent copper, 10·5 per cent tin, 1 per cent zinc, and 0·5 per cent phosphorus is suitable for bushes to form watertight joints, and for castings required to have much strength.

Alloy additions to non-ferrous metals have greatly increased in importance. Nickel, chromium, and beryllium, together with other alloys, are playing increasingly important roles in the production of high-duty, non-ferrous castings. It has been found that certain alloys can be hardened by heat-treatment, among these being the high conductivity copper alloys, such as those containing 0·8 per cent chromium and 0·08 per cent silicon; 3 per cent nickel and 0·6 per cent silicon; 0·4 per cent chromium and 0·1 per cent beryllium; the remainder in each case being copper. Nickel additions are now frequently used, and of particular interest is the bronze containing 88 per cent copper, 5 per cent tin, 4 per cent nickel, and 2 per cent zinc. This alloy resembles Admiralty gunmetal, but since it is susceptible to heat-treatment, castings can be produced having mechanical properties comparable with high tensile brass.

Bearing bronzes usually contain lead, the amount varying with the load on the bearing and the shock to which it may be subjected. The lead reduces strength, but facilitates lubrication. A mixture suitable for high speed and medium pressure consists of

75 per cent copper, 5 per cent tin, 12 per cent zinc, and 8 per cent lead. Gear bronzes need to be tough, and phosphor tin is frequently added to cleanse the alloy ; 88·7 per cent copper, 11 per cent tin, and 0·3 per cent phosphorus provides a suitable mixture for such work. A specially hard bronze is sometimes needed for bushes and bearings, and a composition consisting of 83·5 per cent copper, 14 per cent tin, 1·5 per cent zinc, and 1 per cent lead will give such a bronze. Speculum metal consisting of 66 per cent copper, 33 per cent tin, 0·8 per cent zinc, and traces of arsenic is an extremely hard, white bronze capable of taking a very high polish. It is difficult to cast without blemish. Aluminium is alloyed with copper to form aluminium bronze, a very strong composition being 86 per cent copper, 8 to 9·5 per cent aluminium, 2·5 to 4 per cent iron, with a maximum of 0·5 per cent tin and impurities not exceeding 1 per cent.

The alloys of copper have a great affinity for oxygen, and in the making of mixtures, particularly from virgin metals, it is necessary to prevent air coming in contact with the metal when melting. Charcoal should be used as a covering when melting copper, and, in some cases, it may be held below the level of the fluid metal to remove oxygen. A better plan, however, is to make use of phosphorus, manganese, or silicon. These enter into the whole metal mass, and form oxides which form scum on the metal. Zinc is an important deoxidizing agent, and because of this, brass is not subject to oxidization to the same extent as bronze. Zinc is frequently added to a bronze to purify the composition. Tin and copper oxides do not readily rise to the surface, and become entangled in the crystalline structure as the alloy solidifies, thus forming a source of weakness.

In melting copper-zinc alloys, or copper-tin-zinc, there is a loss of zinc due to oxidization varying from

1 to 5 per cent. This is due to the reduction of copper and tin oxides and the formation of zinc oxide, and also to the volatile nature of the zinc. The amount lost varies with the mixtures used and the melting conditions. Due allowance must be made for this loss in the charge ; a common practice is to add spelter before casting the alloy, and, when stirred, in addition to making up loss, it gives the alloy a final cleansing. Phosphorus in the form of phosphor tin or phosphor copper also has remarkable cleansing properties. Silicon gives satisfactory results in reducing the oxides of copper when a pure form of copper is required to be cast, but it is not used much in the alloys of copper. Manganese is also a deoxidizer, its inclusion strengthens brass, but reduces ductility and increases shrinkage ; added as ferro-manganese, the iron is a source of strength.

Alloys of copper are frequently cleaned by means of a non-metallic flux, a common one for brass being known as salt cake. This consists of chalk (5 parts), silver sand (15 parts), coal dust (5 parts), and bone ash (20 parts). It is used to cover the metal, and is stirred in when the metal is fluid.

In connection with the bronze containing 5 per cent nickel the procedure is somewhat different from that for Admiralty gunmetal. The copper and nickel are melted down, using a moderately oxidizing flame, and when thoroughly melted deoxidized with 15 per cent phosphor-copper (3 oz. per 100 lb. of metal). The zinc is added and then the tin, and the deoxidization completed by a further addition ot 4 oz. of phosphor-copper per 100 lb. of the melt.

BRASS AND BRONZE MOULDING

The principles of moulding applied to iron and steel are, in a general sense, applicable to brass and bronzes, but modifications in practice are necessary to cope with the special characteristics of the varying compositions of non-ferrous alloys. In the brass foundry, moulds are more generally made in boxes, comparatively little work being done in the foundry floor, and bench moulding is more common than in iron and steel foundries. This is due largely to the fact that brass castings are smaller by comparison.

The use of silica sand bonded with various resins, oils, gums, and molasses has been common with the founding of non-ferrous alloys for many years. Such mixtures, when baked, have many advantages, and on account of these, some extension has taken place recently in their use for moulds as distinct from cores. A frequent practice in non-ferrous founding, as in iron founding, is to use a mould constructed in such a manner that a differential rate of freezing takes place in different parts of the casting, usually to compensate for differences in mass or section of the casting, or to ensure greater soundness, or hardness at vital working points. This is the method known as "chilling," where a metal of relatively high thermal conductivity, usually copper or cast iron, is incorporated in the sand mould at the points where such densening is required. Even with the use of occasional chills, however, sand moulds do not give results equal to those obtained from metal moulds, but economical considerations necessitate that sand moulds be used for all but exceptional cases when the number of a particular size and type of casting warrants the cost of a metal mould.

Small light castings, where the quantity is not sufficient to justify a metal mould, or where the alloy or the design of the casting is not one which lends itself readily to such production, will continue to be made by the green-sand method of moulding. Where important castings of anything above the lightest weights are concerned, most brass foundries prefer a dry-sand mould on account of the greater strength and reliability of such moulds and because of the advantages they offer in the production of sound castings. With the increasing use of sand control, however, the use of green-sand moulds tends to increase. Such moulds give sharper castings, less flash, and frequently smoother surfaces, with the result that fettling costs are less. Even though there is a tendency to cast larger work in green sand than formerly, the size of castings so made is not generally so large as with iron castings. This difference in practice is more noticeable with the various bronzes; phosphor bronze, for instance, is an extremely active alloy and very searching in its character, and, if poured into green-sand moulds, the castings are so rough that in many cases they would be useless.

Much attention must be given to the casting temperature ; superheating, as in the case of cast iron, would materially affect the physical qualities of copper alloys, and, since they are low in fluidity, dry-sand moulds give better facilities for complete filling at a temperature that would not be injurious to the alloy. All bronzes, however, tend to eat into the sand considerably, and are liable to cut green-sand moulds and to cause scabbing.

Green-sand Moulding. It is common practice to prepare green-sand moulds over a trough containing the green-sand mixture as shown in Fig. 5. Especially is this so in small foundries, where the floor is used for dry-sand moulding and is made up of suitable sand for the purpose. The quality and condition of the sand used is an important factor, but the grading of its fineness should not be overlooked. A fine-grained sand suitable for small castings would tend to scab if used for large castings. Pouring temperatures of alloys used are generally lower than those for iron mixtures, and sands that can be used for iron are also suitable for the brass foundry. Mansfield and Birmingham sands are representative of the red sands suitable for both green- and dry-sand work. The mixtures vary in strength to suit the work, special facing sands being rarely used for small work, new sand being added to that in the trough from time to time. For larger work, however, that may be made in green sand and,

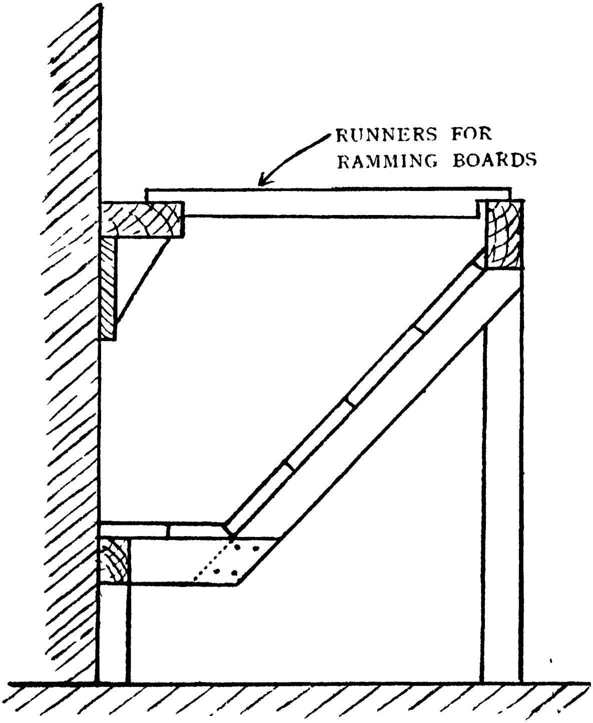


FIG. 5. PREPARATION OF GREEN-SAND MOULDS OVER A TROUGH

especially in the case of bronze, a facing mixture containing coal dust may be used.

The moulds require to be rammed to a greater density than similar moulds for cast iron, more particularly at the face, in order to obtain good surfaces on the castings. Venting is just as necessary as for cast iron, and there is greater need for needle vents and risers because the metal solidifies quickly, and any pressure of gases on the top surfaces may prevent the complete

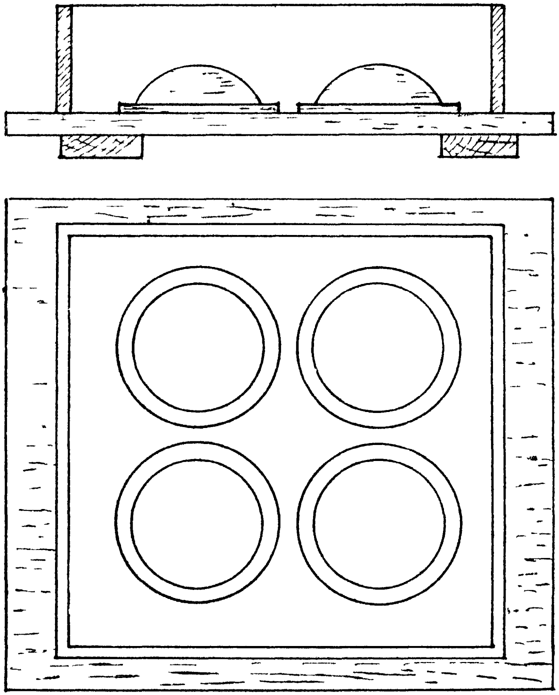


FIG. 6. PREPARED COPE FOR CAP MOULDS

filling of the mould. When special facings are used—they are not always necessary—one of the best for brass is ordinary flour. This preserves the good colour that is desirable, and also gives a smooth skin. It may be dusted and the mould subsequently sleeked, but the use of a camel-hair brush is equally as effective and easier than sleeking; any surplus facing should be removed. For the bronzes, graphite or French chalk is suitable.

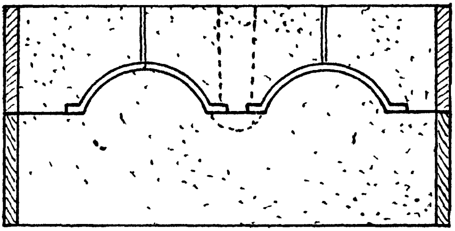


FIG. 7. SHOWING NEEDLE VENTS

Moulds are invariably made by the turnover process, and pattern plates for hand moulding are in common use, particularly for work having a varying joint; but the ordinary ramming board or an odd side is frequently used when the number of similar castings does not warrant the making of a pattern plate. The making of a mould for casting caps is illustrated in Figs. 6 and 7. To cast the caps flange down it is advisable to make the cope first, as in Fig. 6, and turn over to form the drag. The ingate as well as the runners is frequently cut after separating the mould parts, and before withdrawing the pattern. Needle vents, or "whistlers," should be made at the top, as shown in Fig. 7. A small valve fitting for a boiler frequently involves a three-part box, as in Fig. 8. The middle part is made first, and a joint is carried to the flange according to the depth of the middle part. These are generally run from the cope joint by way of the branch flange and middle vents, made from the highest points of flanges, and also the body. Cores used in green-sand moulds are invariably dried.

Dry-sand Moulding. The practice prevailing is similar to that for cast iron, but, as boxes are more commonly used, the moulds are dried in ovens, rather than by means of braziers or other special drying apparatus. The moulds, as a rule, being comparatively small, are easily transported to ovens. A good practice is to use a framed bogie upon which moulds are laid. This allows the heat to penetrate the moulds, and is very effective. Dry-sand moulds are frequently given a facing wash while green, a very satisfactory wash, particularly for the phosphor bronzes, being composed of graphite bonded with china clay. In some cases a thin solution of china clay only is used, but the sand does not "peel" so well as when graphite is present;

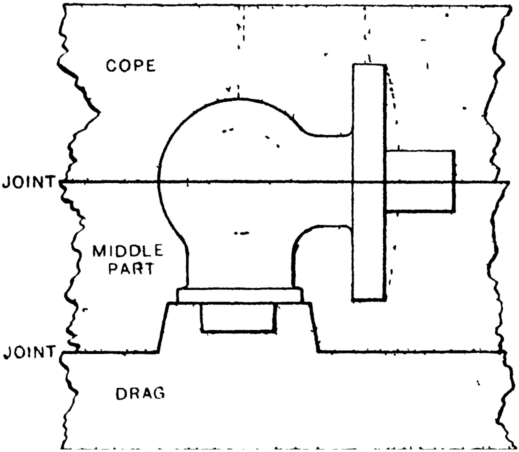


FIG. 8. USE OF THREE-PART BOX

it may, however, be used for the larger brass castings. Chills are used in moulds to an extent comparable with those for steel castings. They are necessary to secure, as far as possible, uniformity in the rate of cooling.

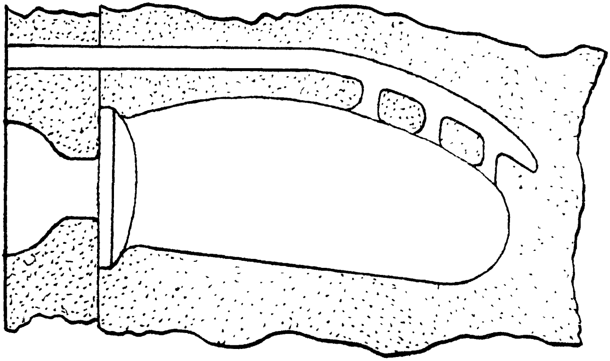


FIG. 9. FEEDER HEAD IN PROPELLER BLADE MOULD

When a metal chill forms a considerable part of a mould, water may be circulated in it to absorb the heat, but this method is confined to special work. The surface of the chill should be polished with a mixture of lard and either French chalk or graphite.

Runners should have ample area, and risers are as necessary as for steel. Feeder heads are necessary on bronze castings when the design of the casting will admit the use of one, and particularly is this so of manganese brass as in the case of propeller blades. These are invariably cast on end, the metal entering near the tip of the blade, as in Fig. 9. It is a good plan to prepare a very large receiver, or sow, into which all the metal to cast the job is poured, and then uncover the downgate. Metal enters the mould with considerable force, which is gradually reduced as the head pressure is reduced. Liners, too, are invariably cast on end, although a head is frequently cast on of the full diameter ; a type of head shown in Fig. 10 has economical advantages in the use of head metal It will be noted that a covered runner is prepared and connected to a series of gates. The top pouring of a plain cylindrical casting of this kind has the advantage of keeping the top metal agitated and hot, so that dross is likely to rise.

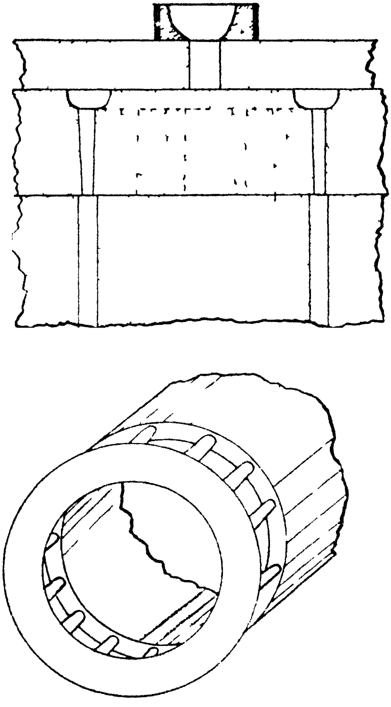


FIG 10. FULL DIAMETER HEAD CAST ON LINER MOULD

Many brass and bronze castings are thin in section, and, when fairly large and of irregular shape, it is sometimes an advantage to make the core in place rather than depend upon a core-box. This method is economical, particularly if only a few castings are

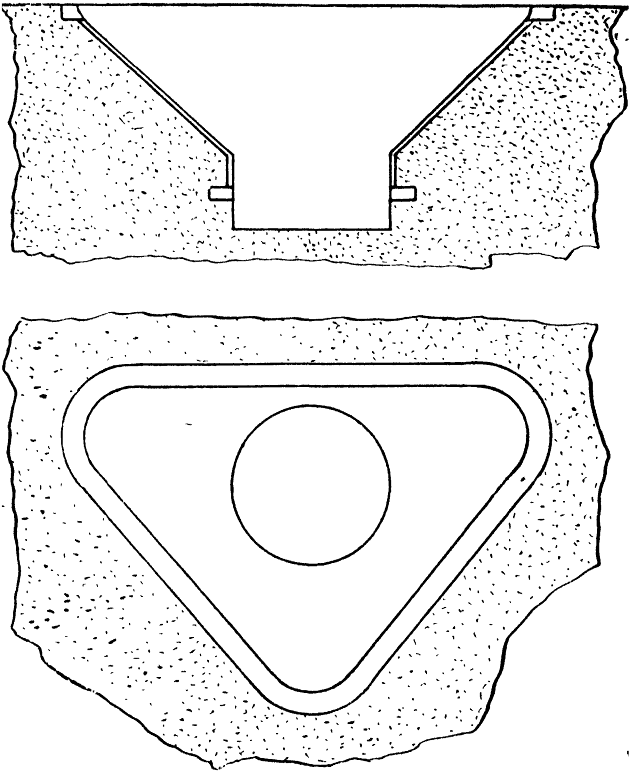


FIG. 11. CORE SKELETON FOR CONDENSER DOOR

required, as a cheap skeleton may be used, as for the condenser door in Fig. 11. With such castings it is important that the flanges are in correct relative positions, but the shape of the metal connecting them is not important, excepting that the thickness must be regular. The mould must be made in the floor, and, after withdrawing the pattern, thickness strips are laid in corresponding to the thickness of the metal. Wood strips may be used for the flat surfaces, and either loam or clay strips for the curved shapes, completing a shape in which the core can be rammed. The core should be carefully marked to coincide with a mark on the joint, otherwise considerable difficulty would be experienced in locating it after lifting to remove the thickness.

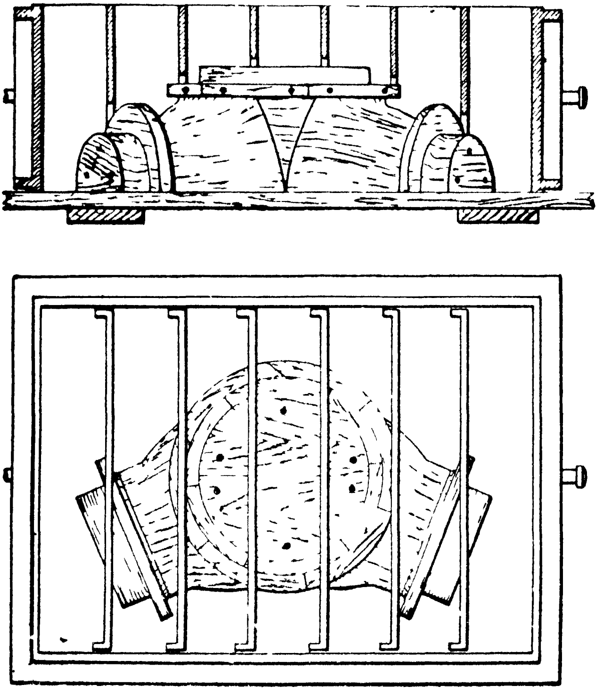


Fig. 12. Preparation of Drag for Bronze Valve

This is common with the setting of all irregular-shaped cores, even when made from core-boxes.

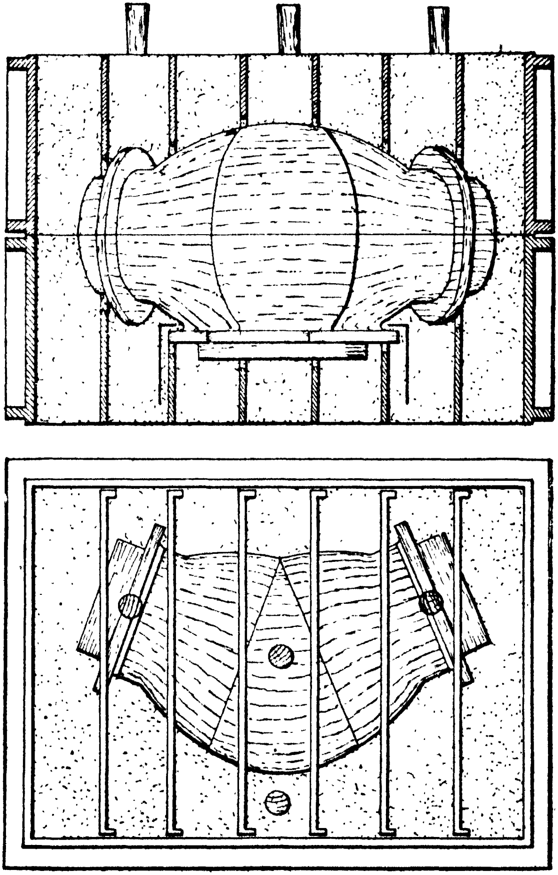


FIG. 13. MOULD AFTER BEING RAMMED

The making of a large bronze valve is representative of a medium-sized casting, the mould for which is made by the turnover process. In Fig. 12 the drag is being prepared, while Fig. 13 shows the mould rammed with riser and runner sticks in position. Chills should be used at the junction between the flanges and the body.

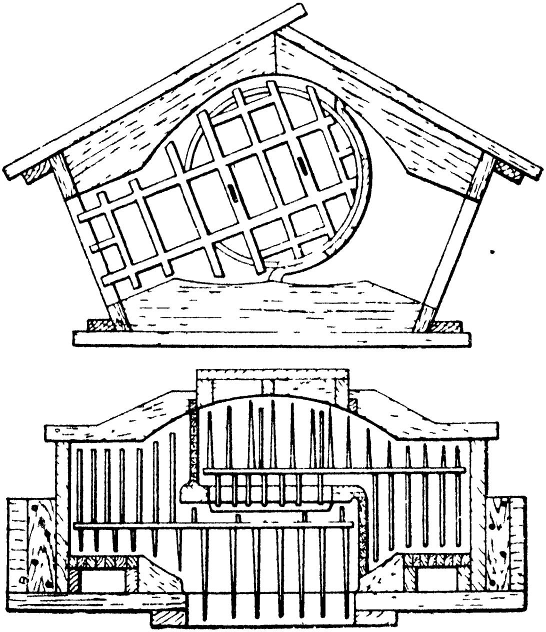


FIG. 14. METHOD OF SUPPORTING LARGE CORE

In some places, such as behind the cover flanges, gaggers are an advantage, but the use of straight iron rodding, set in horizontally, frequently gives all the support necessary. The core-box supplied for such work generally represents the full core, but it is necessary to make a joint to remove the pattern sections, thus two cores are made and secured after they are dried. Special grids are necessary for the core, and Fig. 14 shows a suitable method of supporting the core when a natural bonded sand, commonly associated with very large valve bodies, is used. The top half-core is cut away to give access for bolting the two parts together, after which sand is rammed in to complete the shape.

Whatever method of gating is adopted, the metal is bound to impinge against the core ; a good method is to use a tangential runner, as shown in Fig. 15, and one entering the partition between the cores. Risers should be drawn for the high points as indicated.

Loam Moulds. The proportion of loam work done in the brass foundry is comparatively small. Full patterns are generally supplied, and sand moulds are more readily prepared. Loam is only used for making moulds for work of an exceptional character, such as the propeller illustrated in Fig. 9. The pitch surface of the plate is conveniently swept on a building plate, and, after being dried and the shape of the blade defined, is thicknessed to form a sand pattern from which the cover is made.

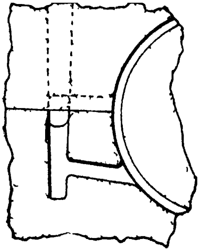


FIG. 15

Moulds for bells are also made in loam. With these castings precautions must be taken against irregular contraction, this being one of the most important problems, as any irregularity interferes with the tone of the bell.

It is mainly for cores that loam fills a special need in the brass foundry, and more generally for cylindrical cores that are swept on a horizontal spindle. Comparatively little work is swept about a vertical spindle, but, when necessary, it is prepared in a manner similar to that for cast iron.

In pouring either brass or bronze castings, no time should be wasted; the moulds should be filled as quickly as possible to reduce losses by oxidization, and much depends upon the temperature of the metal at the time of pouring. It is not possible to give pouring temperatures for the wide variety of mixtures in use; the sectional thickness of the casting to be poured, as well as the particular alloy, must be considered, and experience in judging temperatures is essential. In the case of Admiralty gunmetal, for instance, Dr. Carpenter recommends a casting temperature between 1120° and 1270° C., but it is more frequently cast at temperatures varying from 1120° to 1160° C., while aluminium bronze, say, for heavy valve bodies, should be cast at a temperature of about 1100° C. It is profitable to make use of a pyrometer to determine the temperature of the metal at the time of pouring.

The thermo-electric pyrometer is more generally preferred. It consists of two parts, the thermo-couple and indicator or galvanometer. The device is based on the principle that by heating the junction point of two dissimilar metals an electric current is generated. The junction is formed by welding the two wires together, one of which is usually platinum, and the other an alloy of platinum with 10 per cent iridium or rhodium, though not always, and these are encased in a protective sheath or tube. This tube is fitted to what is known as the cold junction box, in which the wires are connected to terminals from which a connection is made to the galvanometer. When this instrument is used it is inserted into the metal, and, as it becomes heated, a needle moves along the chart in the indicator which registers the temperature.

While the instrument described is extremely useful as a check on temperatures, it should not be used for every job to be cast, but to supplement the judgment and experience of the founder.

ALUMINIUM FOUNDING

In its pure metallic state aluminium does not possess good foundry characteristics, and in castings its mechanical properties are low. In this state the metal is generally used for those purposes where its high electrical conductivity or its chemical properties are of paramount importance. For castings, aluminium is almost invariably alloyed with small percentages of other elements such as silicon, copper, manganese, nickel, and magnesium. The addition of carefully controlled small quantities of these elements improves the foundry characteristics and the mechanical properties of the castings, while the latter may be further enhanced by suitable heat-treatment.

The useful characteristics of aluminium alloy castings lie in their light weight, relative ease of production both in sand and chill moulds, high strength, especially heat-treated alloys, excellent corrosion-resistance, good finish and machining qualities, and high thermal conductivity. Sand casting is normally employed for the larger types of castings, and is responsible for by far the greater bulk of aluminium alloy castings; it is the process employed when only a moderate number of castings of similar size and shape is required. Where larger quantities of similar castings are involved it may be more economical to adopt either the gravity or pressure die-casting process. Compared with sand casting, either of these die-casting methods gives greater accuracy of production, a better surface finish, enables thinner sections to be successfully cast, and, generally, the resulting castings have greater strength when similar alloys are used.

The production of aluminium alloy castings was developed largely in the brass foundry, and with some firms it is still regarded as part of the brass foundry

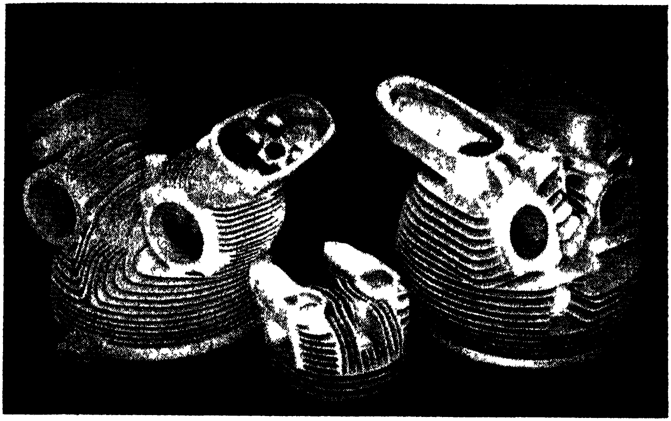


FIG. 16 AIR-COOLED CYLINDER HEAD CASTINGS FOR RADIAL AIR ENGINES IN HIDUMINIUM R R. 53

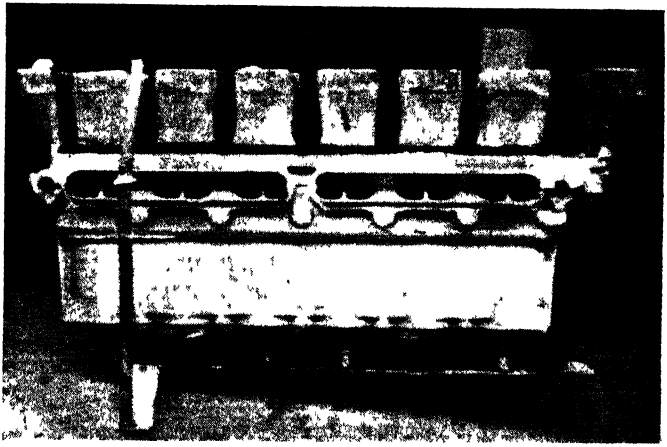


FIG. 17. AERO ENGINE CYLINDER BLOCK CASTING IN HIDUMINIUM R.R. 50, SHOWING RUNNERS AND RISERS

work. During the past twenty-five years, however, there has been very great progress in the development of suitable alloys to meet the demands of various industries, and foundry technique has been developed to facilitate the production of sound castings, and it is now generally recognized that greater efficiency is obtained when the castings are produced in foundries allocated to this class of work. The motor and aircraft industries use the bulk of these castings, but their use has rapidly increased in recent years and, in addition to other transport industries such as railway rolling stock and shipbuilding, aluminium alloy castings are being increasingly employed in the electrical, chemical, and dairy engineering industries; in fact there are very few industries in which they are not used.

Sand Casting. In the sand casting of aluminium alloys the method of moulding involves similar principles to those for other metals and alloys with modifications in technique to suit the peculiarities of the alloy to be cast. The difficulties in the production of sound castings are largely due to the high contraction of these alloys, coupled with the fact that they are very weak just after solidifying. It is very important that moulds should be made weak enough to crush under the comparatively light pressure of the contracting metal. When the resistance is too great the castings crack, the strain being carried in them to a less extent than in either cast iron or steel. Abrupt changes in the metal thickness are a source of trouble, and should be avoided whenever possible, as the irregular sections not only tend to draw and cause spongy metal, but set up irregular strains during the period of cooling. When a regular thickness of metal is impossible, steps must be taken to equalize the rate of cooling, and to introduce feeders from which heavier sections can draw metal when they are shrinking. To regulate the rate of cooling, metal chills are being increasingly employed. These may be of cast iron or, preferably, a copper alloy, and are made to the required shape of the part against which they are to be placed. Chills are frequently used in preference to risers or feeders, but, generally, it is advisable to use a feeder on heavier parts when its use is practicable.

Whatever the type of mould, it is necessary to make ample provision for the entry of the metal. Although aluminium is a very active metal when fluid, it solidifies very quickly owing to the temperature being kept as low as possible, and the runners should be large to enable moulds to fill quickly. While quick filling is desirable, particularly with sand moulds, it is important to avoid turbulence of the metal in the mould, otherwise an oxide is formed which makes the casting porous and weak. In order to preserve a thin film of oxide on the surface it is better to fill the mould from the bottom when the oxide will rise with the metal, and as long as it remains unbroken will protect the metal from further oxidization. Apart from the agitation of the metal in the mould, due to faulty running, casting at too high a temperature is the most frequent cause of faulty castings. In dealing with quantity production, there is a tendency to cast too many moulds from one ladle of metal, and those cast first are frequently porous as a result of the higher temperature necessary to maintain fluidity to complete the casting. As castings vary in shape and sectional thickness, and also in composition of metal, the pouring temperature will necessarily vary and, when faulty castings are being produced, it will be found profitable to experiment, pouring moulds at gradually reducing temperatures and checking the results. The metal should generally be as cold as will allow the complete filling of the mould.

The strength properties of aluminium alloy castings can be greatly affected by the position and types of the gates used. In general multiple gating is recommended as it allows a lower pouring temperature and a uniform but rapid rate of solidification in all parts of the casting. The gates should be arranged in such a manner as to promote progressive feeding—that is, sections remote from the gate should be first to solidify. If light sections are adjacent to heavy sections the gates should normally be placed on the lighter sections. For alloys that oxidize quickly the use of skim gates is often advisable.

Most aluminium castings are made in green-sand moulds, and green-sand cores are used to a greater extent than in moulds for other metals and alloys. The skin drying of moulds and cores is practised to a considerable extent. Skin-dried moulds reduce the action between the aluminium and the moisture, while at the same time maintaining a weak mould. Considerable attention should be given to the grading and tempering of the sand. Generally, a finer-grained sand should be used of open texture, particularly for cores, and the amount of moisture present should be just sufficient to make it cohesive. The sand used should be quickly disintegrated after the metal is poured in order that the casting may have reasonable freedom to contract. It is more porous when the moisture content is kept low. When the moisture is unevenly distributed there is a tendency to get damp places on the face of the mould, and these cause sponginess in the casting.

Aluminium is very active in a fluid state ; it decomposes the water, and is liable to absorb gases formed. Facing sands are not so necessary as for iron, steel, and brass moulds. Care should be exercised in ramming the sand. It should be lightly rammed, just sufficient to take the impression and withstand the rush of metal when casting. The lower the moisture content of the sand the heavier the ramming can be, but generally the density should be less than for a similar mould to receive cast iron. When the design of the casting is such that the mould offers no resistance to the contraction of the metal, less attention need be given to the ramming. Machine moulding is practised to a considerable extent, and this has the advantage of giving regular density and better control of ramming

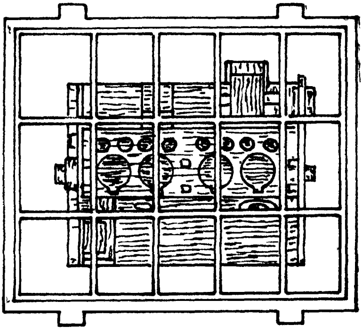


FIG 18 PREPARATION OF DRAG

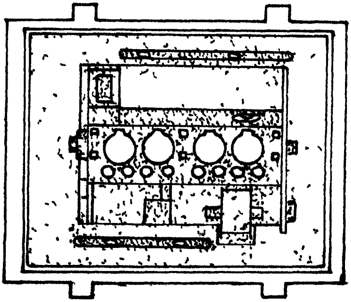


FIG. 19. PLAN OF DRAG

Moulds are almost invariably prepared by the turnover process, and Fig. 18 shows the preparation of the drag for the main part of a crankcase. Adopting this method, the drag carries practically the whole of the mould, and the cores are more easily located with little likelihood of crushing during the time of closing. The mould could be prepared to cast the flange down, but it would involve a three-part box, and the method would be costly and inconvenient for adoption on a moulding machine. When the flange is cast up as indicated, bottom pouring is a little more difficult, but there are several ways of running at the bottom. Prepared runners may be located at the time of ramming, and connecting gates rammed in the cope, or portions may be printed off and cores used to carry the runners to the bottom. Horn gates may be used instead of either of these methods. At least four runners should be used, two on each side, and two channels should be formed on the joint, connecting the runners on each side with two ingates through the cope.

If both drag and cope are made on plates and either mechanically or hand rammed, the former is preferably turned over for stripping, particularly if it is a deep strip, but, when made on machines not fitted with a turnover and stripping device, the plate and pattern may be lowered or the mould lifted according to the type of machine used. A plan of the drag is shown in Fig. 19. Care is necessary in arranging risers in the cope. All thicker parts of the casting which have direct contact with the flange should have a riser for feeding, and those parts not in contact with the flange should have chills introduced, either when ramming the mould or in the preparation of the cores.

The cores for work of this kind necessitate considerable attention. In this instance they are preferably baked. The sand used should be easily disintegrated by the heat of the metal and very porous. Naturally, bonded sands are usually too strong and offer too much resistance to contraction. For most dry-sand cores, a silica sand with a fineness of from 70 to 90 will be found adequate when bonded with one of the many artificial bonds. Resin is successfully used as a bond, either alone or with flour. A suitable core sand consists of 3 parts of washed sand to 1 part of used sand, adding 1 part of resin to, say, 20 parts of sand. The resin content varies with the intricacy of the cores to be made. The sands should be mixed dry, the powdered resin incorporated, and the mixture damped to a working condition. When made, the cores should be baked, but the temperature of the oven should not exceed 180° C Resin-bonded cores are removed while the casting is hot Figs 20 and 20A show a number of cores necessary for the crankcase, and Fig 21 illustrates a plan view of the mould cored-up and ready for covering.

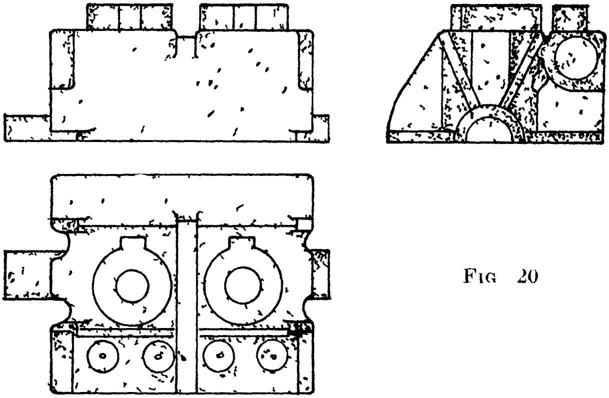


FIG 20

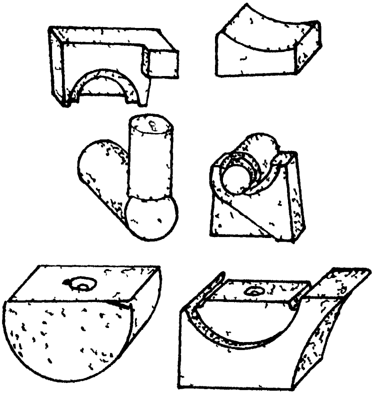


FIG 20A CRANKCASE CORES

Pistons when of aluminium are usually made in chills, a mould for which is shown in Fig. 22. The moulds, which may be of cast iron or steel, the latter giving longer life, are divided along the centre, the halves being held together by screw clamps. The cores are generally made in metal core-boxes, and given a facing wash before being baked. When the core has been set and the mould secured, metal is poured by way of the gudgeon bosses, the mould being opened directly afterwards and the core sand dislodged.

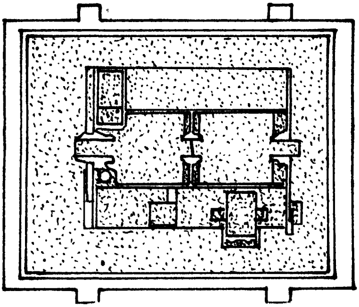


Fig. 21. Mould Cored-up

Another form of casting which sometimes causes difficulties is illustrated in Fig. 23. It represents a cover, the metal usually not being more than ¼ in. thick. The open end is usually cast down, because hanging the core in the cope is inconvenient and running the metal would be difficult. In making the moulds for smaller covers of this kind, a turnover pattern plate is commonly used from which the core is made direct, but generally the larger castings have a separate core. Spray runners on the joint and to the flange, and suitable risers from the high points as indicated in Fig. 24, are necessary. The internal bosses,

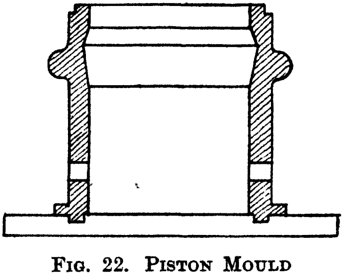


Fig. 22. Piston Mould

which are carried the full height, should each have a riser, otherwise the casting would be drawn.

It is sometimes stated that moulds for aluminium need not be vented, but an examination of the waster castings produced will invariably indicate the need for venting. Aluminium castings do not blow to such an extent as iron castings, but gases are generated that must find a ready exit from the mould, and, unless direction is given to these gases by venting, the casting is liable to be blown. Owing to the low density of these alloys, the height of head would need to be about three times that of cast iron for a similar pressure, and the provision of such a head would not be practicable; the resistance to the pressure of gases is comparatively low. Close attention to venting, particularly in pockets, will reduce the pressure of gases against the metal and,

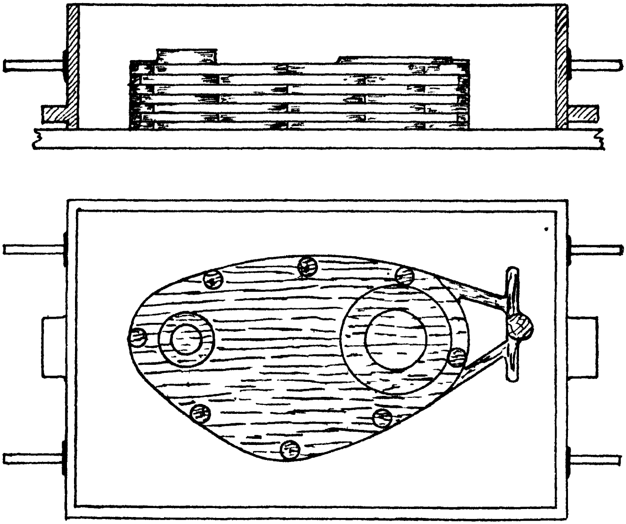


Fig. 23. Casting of a Cover

at the same time, relieve possible air traps. Blowholes, however, may be caused by moisture on chills, a patch of sand forming the face being damper than the remainder, or the temperature of the alloy being too high.

Moulds for aluminium castings are frequently faced with graphite to improve the skin, but apparently some carbon is absorbed by the metal which darkens the colour. Powdered soapstone or French chalk is more suitable for the purpose, and it is preferably applied with a soft brush after being dusted on The need of clamping or weighting the mould preparatory to casting is not so great as with metals of a higher density , with small moulds the weight of the cover box is generally ample, but with the larger moulds clamps or weights may be necessary. A rough calculation can quickly be made, allowing 1 lb. per sq. in of area for each 10 in. of head.

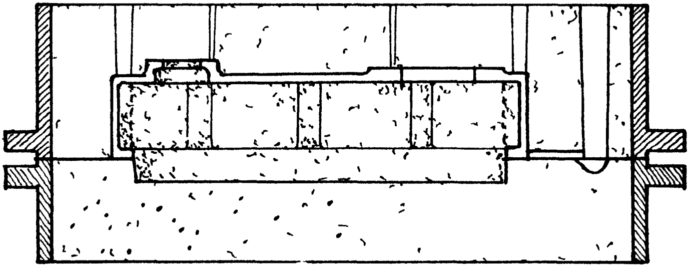


FIG 24 SHOWING SPRAY RUNNERS AND RISERS

DIE CASTING

There is considerable difference between the gravity and pressure die-casting processes. The gravity process, frequently referred to as permanent mould casting, follows to a large extent the technique of sand casting, but the moulds, and usually the cores, are of a more permanent character, and are made of cast iron or steel.

Pressure die-casting, by comparison, is more highly mechanical and manual operations are reduced to a minimum, but the radical difference between the two processes is that in pressure die-casting the metal is forced into the die under high pressure, with the result that thinner sections can be cast and the castings so produced are more accurate.

There are several groups of aluminium base alloys, which represent a considerable part of the bulk of die-castings produced, and of these the aluminium-silicon alloys are of particular interest in pressure die-casting. These alloys have a high fluidity, and they are sufficiently fluid just above their melting point to enable them to be pressure cast at a lower temperature than is usual with the other alloys. This adds to the die life, and the castings are more likely to be sound.

In producing die-castings by the gravity process, it is necessary to lay down and follow a well-conceived and clear-cut procedure in order to avoid porosity, shrinks, and cracks. It is important to guard against agitating the fluid metal, otherwise blowholes in the castings will result. To avoid cracking, cores must be withdrawn gently and at the right moment, and temperature and feeding must be carefully controlled. Probably the most difficult of the problems presented are those due to shrinkage. Indeed, although many methods are used for combating shrinkage, it is doubtful whether any one is completely satisfactory. The die should be so designed that it facilitates rapid stripping of the casting, so that contraction of the casting will not be unnecessarily obstructed.

In the pressure process a hydrostatic pressure of between 100 lb. and 500 lb. per sq. in. is required to force the metal into the die cavity and hold it there until it solidifies. Special alloy steels are necessary for the dies, as ordinary carbon steels tend to be corroded or dissolved by aluminium alloys. Heat-treated chromium-vanadium steels are often used for this purpose. Pressure die-castings are usually small and when very large quantities of castings are required, it is often more economical to make the dies capable of producing two or more castings at one shot. Dies are frequently built to produce as many as twenty castings at one shot. Great dimensional accuracy and very close tolerances indeed are possible. For special purposes, castings have been produced in commercial quantities with limits of 0·001 in. across the parting line. Thinner sections can be obtained by pressure die-casting than by any other method. A uniform wall of 0·080–0·100 in. can be quite easily obtained in castings as large as the available equipment can produce.

The merits of the gravity process are worthy of consideration from an economic point of view when the annual requirements of a particular casting necessitate about 500 and less than 5000. The weights of these die-castings can be more easily controlled than those of sand castings. For products such as pistons, where soundness is important, gravity die-castings will be found to yield good results. Castings weighing over 50 lb. each are made by this process, but the greater number do not exceed 10 lb. each. The pressure process may be adopted for bulk quantities of 5000 and upwards; complicated castings of over 7 lb. in weight can be produced in quantities of over 100,000. This process gives fine detail, and the resulting castings are usually accurate enough to represent the finished job; it is particularly useful when the castings require to have inserts firmly and accurately located.

MELTING ALUMINIUM ALLOYS

Although the preparation of moulds for aluminium alloys involves considerable skill, the production of uniformly sound castings is largely dependent upon the melting procedure adopted. Very careful control is necessary—the temperature of the molten metal, for instance, should not be raised unnecessarily above 750° C. High melting temperatures cause excessive oxidization and gas absorption and when the temperature exceeds 770° C. an increase in the grain size of the metal in the castings will generally result. Apart from control of temperature, the importance of cleanliness in all the casting operations cannot be overestimated.

In principle the furnaces used for melting aluminium alloys for castings do not differ from those used in the brass foundry. They are of two types—direct flame furnaces, in which the heating medium comes into direct contact with the metal, and indirect flame furnaces, in which the heat is transmitted through an intermediary. Open hearth and rotary furnaces, in which metal is heated by the direct flame, are suitable for alloying large quantities of metal; generally, however, the indirect flame furnaces are in more common use. Of the latter the tilting furnace has largely displaced the lift-out crucible type of furnace with a graphite crucible, though this type has some advantages in the casting of aluminium-silicon alloys. Cast-iron pots are gradually being preferred to graphite or refractory clay crucibles, because of their better thermal conductivity, superior strength, lower cost, and greater facility of production. It is necessary, of course, to avoid contamination of the aluminium alloy with iron, and for this reason the inside of the iron pot should have a protective coating. For this purpose a wash consisting of whitening, 5 lb., water, 2½ gals., and sodium silicate, 3 oz., applied with a brush and dried, will be found effective.

As a rule gas or oil is the fuel used for melting aluminium alloys. Electric furnaces, so far, have been used but little for this metal in the foundry, but their possibilities are of increasing interest, especially low-frequency induction furnaces, which are particularly useful in the production of die-castings when the molten metal is required to be held at a definite temperature.

The ability of aluminium alloys to absorb gases increases rapidly with temperature and with the time the metal is held in a molten state. Such gas absorptions are likely to cause serious porosity in the castings. It is important therefore that the temperature of melting should be as low as possible and efficient pyrometric equipment is advisable. Agitation of the metal in the furnace should be avoided as much as possible, since oxides formed in this way are only partly removed by skimming and are often trapped in the casting. Fluxing is not usually necessary, but it is useful in minimizing dross losses, especially when considerable scrap is included in the charge. In such cases, active or inert gases, volatile fluorides and chlorides, or stable metallic salts may be used. Of these, aluminium chloride, or a mixture of chlorides and fluorides, or cryolite, are most commonly employed, or one of the many proprietary fluxes may be used. Solid fluxes must be absolutely dry and introduced into the metal in a way that avoids excessive agitation. Gaseous fluxes should be led into the bottom and allowed to bubble up through the metal.

Many of the alloys generally used are available in ingot form ready for melting in the foundry, but if the alloy to be cast is made up in the foundry, the aluminium is first melted and, at approximately 700° C. to 750° C. temperatures, the necessary alloying elements are added, generally in the form of key or master alloys containing aluminium and a known high percentage of the alloying element. Usually the order in which alloying elements are added is as follows: Copper, silicon, iron, manganese, nickel, magnesium.

To modify, or refine, the aluminium-silicon alloys, sodium is added to the melt and care must be exercised to reduce difficulties encountered. Sodium can be added either by fluxing with sodium containing salts or by the direct addition of metallic sodium; the latter method is more general and the sodium used should be wrapped in aluminium foil and pushed to the bottom of the molten metal by means of a suitable plunger. The amount of sodium added should be about 0·05 to 0·1 per cent by weight of the melt. The molten metal should stand about ten minutes, after the introduction of the sodium, before casting.

CASTING ALLOYS

Although much research has been devoted to heat-treatable alloys in recent years, the majority of aluminium alloy castings for general engineering purposes are made from alloys which are not heat treated. Of these the aluminium-copper and aluminium-copper-zinc alloys, so popular in the early years of this century, are still used in important quantities for ordinary castings. The discovery by Dr. A. Pacz, in 1920, that silicon, when added to aluminium in suitable proportions, gave a very fine structure by means of a modification process, had a great influence in the production of light metal castings and great progress has been made in the application of aluminium-silicon alloys. The excellent casting qualities of these alloys, combined with their corrosion resistance, make them particularly suitable for chemical engineering. Their ductility, either sand- or die-cast, is exceptional, but their elastic properties are inferior. Increasing use is being made of the aluminium-magnesium group of alloys, with a magnesium content ranging from 3 to 12 per cent and containing small percentages of other elements, notably manganese. These alloys possess high strength and are remarkable for their resistance to corrosion, especially against sea-water. Another high strength alloy in the unheat-treated condition is the aluminium-copper-nickel-magnesium alloy familiar as "Y" alloy; this alloy has probably the best elastic properties; its ductility, however, is negligible, but it is used for many types of castings where the maximum rigidity is required.

Heat-treatable alloys have been developed to meet the increasing need for aluminium alloy castings of high strength. These have resulted largely from the aluminium-copper-nickel-magnesium alloy known as "Y" alloy and include the important Hiduminium R.R. series of alloys. While the main constituents of these aluminium casting alloys comprise copper, nickel and magnesium, small percentages of grain refining elements, such as titanium, cerium, chromium, or columbium, may be added. The aluminium-silicon alloys containing small percentages of magnesium are hardened by heat-treatment and their strength increased. The accompanying tables give representative types of aluminium casting alloys.

HEAT-TREATMENT OF CASTINGS

There are three types of heat-treatment practised commercially: precipitation treatment or tempering; solution treatment, involving quenching and a measure of ageing at room temperatures depending on the composition of the alloy; and full heat-treatment consisting of solution treatment, quenching and precipitation treatment. Unlike steel, aluminium alloys do not harden by quenching only and a subsequent low temperature treatment may be necessary to achieve

CAST ALLOYS—HEAT-TREATED

Type	Major Constituents % (Balance is Aluminium)							Commercial Designation
	Cu	Mg	Mn	Ni	Si	Fe	Cd	
Precipitation Treated 150° *to* 175° *C.*								
Aluminium-Silicon-Magnesium-Manganese	—	up to 0·6	up to 0·6	—	11·0	—	—	Alpax Beta 161. D.T.D. 240.
Aluminium - Copper - Nickel - Magnesium with iron, silicon, titanium	1·6	0·1	—	1·0	2·5	1·0	—	R.R. 50. D.T.D. 133B.
Solution Treated 425° *to* 535° *C.*								
Aluminium - Copper - Nickel - Magnesium with iron, silicon, cerium	4·0 2·5	1·5 0·75	— —	2·0 1·3	— 1·2	— 1·2	— —	"Y Alloy," L35. Ceralumin. D. D.T.D. 250.
Aluminium-Copper-Cadmium-Magnesium with manganese, silicon, titanium	2·25	0·8	up to 0·5	—	up to 2·5	—	1·5	Aeral A/H. D.T.D. 294.
Aluminium-Magnesium	—	10·0	—	—	—	—	—	N.A. 350, BA 29, D.T.D. 300.
Solution and Precipitation Treated								
Aluminium - Silicon - Manganese-Magnesium	—	up to 0·6	up to 0·6	—	11·0	—	—	Alpax Gamma 161, D.T.D. 245.
Aluminium - Copper - Magnesium-Nickel with iron, silicon, titanium	1·6	0·5	—	1·0	2·5	1·1	—	R.R. 53C, D.T.D. 255.
With iron, silicon, cerium	2·5	0·75	—	1·3	1·2	1·2	—	Ceraluminium C. D.T.D. 255.

CAST ALLOYS—NOT HEAT-TREATED

Type	Major Constituents % (Balance is Aluminium)						Commercial Designation
	Cu	Mg	Mn	Ni	Zn	Si	
Aluminium-Copper	7·0	—	—	—	—	—	4 L.11, 232.
	12·0	—	—	—	—	—	3 L.8, 260.
Aluminium-Zinc-Copper . . .	2·75	—	—	—	13·5	—	2 L.5, 465.
Aluminium-Silicon	—	—	—	—	—	12·0	L.33, 160.
Aluminium-Magnesium-Manganese .	—	3·0 to 6·0	0·25 to 0·75	— —	— —	— —	Birmabright D.T.D. 165.
Aluminium-Copper-Nickel-Magnesium	4·0	1·5	—	2·0	—	—	"Y Alloy," 218, 2 L.24.

the highest properties. Solution treatment is a high-temperature treatment, carried out either in fused sodium nitrate baths, which allow very close control of temperature, or batch-type electric furnaces with forced air circulation. Uniform heating and an immediate and uniform quench are of the greatest importance. The heating temperatures vary between 450° and 550° C., depending upon the particular alloy. The low-temperature treatment—precipitation or ageing—is usually carried out at between 150° and 250° C. Some alloys attain similar degrees of hardness and strength after natural ageing for a longer period and therefore this treatment is often referred to as artificial ageing. Each alloy should be heated to its required temperature for a specified time.

MAGNESIUM ALLOY FOUNDING

Magnesium alloys possess several advantages which are favourable to their application for industrial purposes, particularly to aircraft and other transporting manufacturing industries, and their application has increased rapidly in recent years. They have a low specific gravity and possess a high strength weight ratio, excellent machining qualities, high resistance to fatigue, and high thermal conductivity. Alloys of magnesium were originally developed for the production of castings, for which they possess favourable properties such as ease of casting and freedom from pinholing. As with aluminium alloys, casting may be produced in sand moulds or, by the gravity or pressure processes, in dies of good quality cast iron.

In sand casting magnesium alloys, many precautions must be taken that are not necessary for other casting alloys. These alloys have a strong affinity for water and will explode in contact with damp sand. The skin-drying or even normal dried moulds, usually prepared for other non-ferrous metals, will not suffice for magnesium alloys, since reaction will render the resulting castings useless. This difficulty is overcome by mixing an inhibitor with the moulding sand, the object of which is to interpose an inert layer between the metal and the sand. Many of the inhibitors used for this purpose are patented. Probably the most commonly used inhibitor is sulphur, which is added to the moulding sand in proportions of about 7 to 8 per cent in combination with 1 to 2 per cent of boric acid. This inhibitor is effective when casting in green-sand moulds, since it produces an inert sulphur vapour and sulphur dioxide when the metal enters the mould and prevents direct contact with the sand surface. The moulding sand must be of high permeability to ensure the escape of gases generated at the time of casting. Synthetic moulding sands consisting of silica sand and a suitable bond are usually prepared in preference to natural sands. A colloidal clay, such as Bentonite, provides a useful bond.

The fundamental principles involved in the preparation of moulds to receive magnesium alloys do not differ from those referred to for other metals and alloys, but, as with aluminium alloys, the arrangement for the entrance of the metal to any mould must limit its turbulence as much as possible so that the oxide skin formed on the surface of the molten metal will not become entrapped in the casting. Particular attention must be given to feeders to ensure the soundness of the castings produced, because the magnesium aluminium alloys are cast at a relatively high temperature and the interval is longer for complete solidification than for aluminium alloys.

The die-casting of magnesium alloys, whether by the gravity or pressure processes, is similar to that for aluminium alloys, but magnesium has practically no eroding effect on the dies and since its latent heat is low the dies may require some external source of heat to maintain them at a suitable uniform working temperature. Care must be exercised in the design of the dies to ensure the easy stripping of the castings, and sudden changes of section in castings must be avoided.

MELTING MAGNESIUM ALLOYS

Magnesium alloys may be melted in coke, gas or oil-fired furnaces, or in electric resistance heated furnaces; probably the most economical and convenient are the gas or oil-fired furnaces. Graphite crucibles are unsuitable as they are rapidly attacked by the metal and fluxes, and steel crucibles, either cast or made from plate, are generally used, though steels containing nickel are not suitable because molten magnesium readily dissolves this element. As a rule, low carbon steels are used for this purpose. Generally the crucibles are more elongated than is customary in non-ferrous foundries, the object being to reduce the area of the molten metal surface so that less metal is exposed to atmospheric oxidization effects. The normal type of lift-out or tilting furnace is suitable, provided it is designed to accommodate the longer crucible.

The use of a suitable flux is essential in melting magnesium alloys, primarily to reduce oxidization but also to facilitate the removal of non-metallic impurities from the melt. Many proprietary fluxes are available, consisting mainly of magnesium chloride and compounded to effect a refining action on the molten alloy. The flux should remove oxide and nitride impurities from the melt, and the products should be readily separable from the metal. Generally, the flux forms a crust on the surface of the molten metal, though a stirring action is necessary to effect proper cleaning of the melt.

The melting point of magnesium alloys is in the range of 600° to 650° C., but for casting purposes superheating to about 900° C. is necessary. Raising the temperature results in considerable grain refinement, and, contrary to experience with aluminium alloys when they are overheated, no appreciable gas absorption takes place. The grain refinement improves the mechanical properties of the alloys, especially after heat-treatment. The casting alloys, are mainly those in which aluminium is the chief alloying constituent; other elements commonly present are zinc, cadmium, and manganese, while copper, silicon, lead, tin and iron are usually present as impurities. Several compositions are marketed under trade names, the most commonly used in the United Kingdom being the "Elektron" alloy series and the range under the name of "Magnuminium," details of some of which are given in the accompanying table.

HEAT-TREATMENT OF MAGNESIUM ALLOY CASTINGS

The mechanical properties of these magnesium alloys are improved by suitable heat-treatment. Those containing aluminium in excess of 9 per cent are susceptible to precipitation hardening by heating to a temperature of 170° C. to 200° C. for a period of 12 to 20 hours. The alloys noted in the table are improved by solution treatment at a temperature of 400° to 430° C. for a period of 20 to 30 hours. The treatment should be carried out in an inert atmosphere. The effect of solution treatment is to increase the ultimate strength and elongation of the alloy, whereas the following precipitation treatment increases the hardness at the expense of elongation.

MAGNESIUM CASTING ALLOYS

Type	Constituents % (Balance is Magnesium)								Specification
	Al	Zn	Mn	Si	Ce	Pb	Fe	Sn	
Magnuminium 18 . **Elektron AZG** . .	8·5	3·5	0·5	0·4 Max.	0·4 Max.	0·4 Max.	0·1 Max.	0·4 Max.	D.T.D. 59A as cast. D.T.D. 289. Solution treated.
Magnuminium 220 . **Elektron AZ. 91** .	9·0 to 11·0	1·0 Max.	0·5	Impu	rities	1·0	max.		D.T.D. 136A, as cast. D.T.D. 281. Solution treated. D.T.D. 285. Solution treated and precipitation treatment.
Elektron AM. 503 .	0·2	0·2	2·5	0·4	0·2	Impu	rities	0·5 Max.	D.T.D. 140A, as cast.

MACHINE AND PLATE MOULDING

Machine and plate moulding practice is the same in both ferrous and non-ferrous foundries, therefore this outline of the practice adopted is applicable equally to iron and brass work.

While all machine moulding is plate moulding, yet many patterns can be mounted either at the bench or on the floor without machines. Machine moulding is for repetition work primarily, but plate moulding practice can be adopted for quite large as well as for small castings of standard design when few castings may be wanted at one time, but the same pattern will be used over a long period. Even for repetition work, if there is not a moulding machine available, greater production can be obtained by mounting patterns on plates. While for large work it might only be practicable to have one pattern or half-pattern on a plate, for small work a number of patterns could be mounted on the same plate connected to each other by runners. The moulding-box faces must be planed for plate work, and the plates must fit, so that when the mould is closed and the metal poured, there will be no overlapping at the joint. The only advantage of this method for large work is that the two halves of a mould can be completed independently, and the moulding boxes only brought together for casting.

When a number of small patterns are mounted on one plate, it is sometimes only necessary to use one side of the plate, both drag and cope being prepared without readjusting the plate. When possible, the patterns are divided into symmetrical halves and secured to one side of the plate, so that impressions taken from each of them will coincide when brought together for casting.

It is generally preferable to prepare patterns separately and secure them to the pattern plate, but many plates are cast with the pattern section on, others being cast in the form of match plates. Fig. 25 illustrates a form of match plate suitable for flanged pulleys. Two impressions would be taken from one side of the plate for drag and cope, respectively, and one from the other side for the middle part, and they would be assembled as shown at Fig. 26. When there is a variation in the width of the flanged pulleys of the same diameter, loose cylindrical metal patterns are prepared in such a way that they can be mounted on the same pattern plate ; as a rule, spigot and socket joints are used for locating the pulleys.

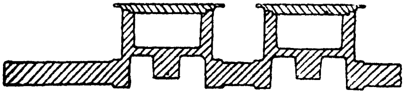


FIG. 25. MATCH PLATE FOR FLANGED PULLEYS

When castings are small they are commonly supplied with metal from one large gate, the various patterns being connected by sprues. This method is often responsible for waster castings, as sprues must of necessity be light to prevent drawing and also to reduce fettling costs, consequently they do not always run. It is better practice to prepare the moulds and runners in a three-part box even when otherwise it would be possible to use a two-part box, the impression of the pulleys being carried in the drag and middle parts, and the cope box carrying the impressions of suitable runners. The method is shown clearly at Fig. 27, which represents a section of the middle and cope parts on a pattern plate. The connections between the runners and moulds are tapered in the reverse direction for stripping purposes, and they have the advantage of feeding the comparatively heavy bosses. The separate plate carrying the runners and gate is shown in Fig. 28.

When castings that have flat tops have to be made, the multiple moulding principle can be adopted. The patterns are mounted on a plate, and each part rammed on the pattern plate, apart from the first one, becomes both a drag and a cope. This is a method that obviates the preparation of separate copes for each drag. The method is illustrated by Figs. 29, 30, and 31, in which a small bush is being made. The range of small castings that can be made in this way is very wide, and includes flanges, neck rings, stuffing boxes, etc.

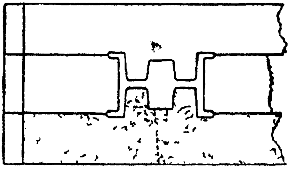


FIG. 26

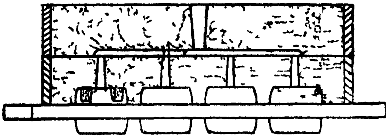


FIG. 27

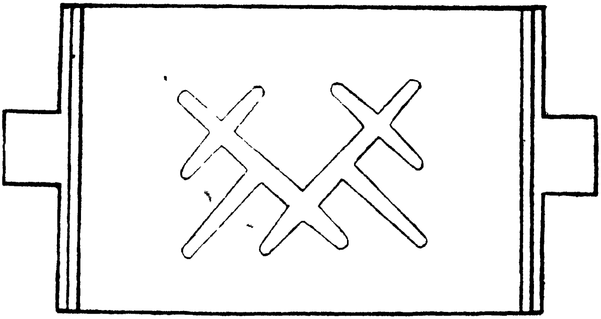


FIG. 28 PLATE CARRYING RUNNERS AND GATE

The runner stick is placed centrally, as shown in the plan view of a finished mould, Fig. 30, while the drag parts, as they are ready, are assembled for casting in the manner shown in Fig. 31. The runner in the bottom part is either stopped off or a brick let into the bed upon which the box rests, this plan being adopted because a brick takes the first drop of metal better than sand does. When a number of boxes has been assembled, it may be six or seven, the flat cope is prepared to form a top, and when this is secured the whole of the moulds can be cast at one time.

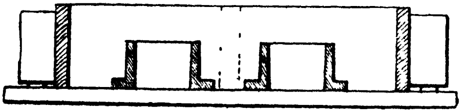


FIG. 29. MULTIPLE MOULDING

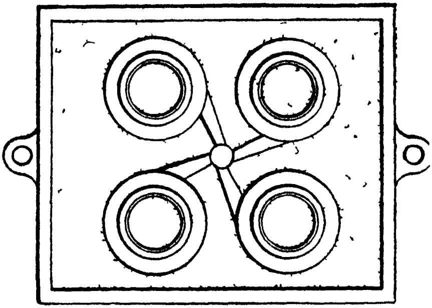


FIG. 30. PLAN VIEW OF FINISHED MOULD

DRESSING CASTINGS

The methods of dressing non-ferrous castings are very similar to those employed for iron castings. Brass castings are often dipped in water while they are still hot to remove much of the adhering sand; the sand is more easily removed from brass than iron. They may be pickled and filed, while chisels and wire brushes are used to rid external surfaces and cores of sand.

Tumbling barrels are employed, but greater care has to be exercised than with iron castings, not only because the metal is more easily damaged, but also because non-ferrous castings are invariably more fragile than iron and steel castings ; for these reasons, non-ferrous castings are better tumbled in water.

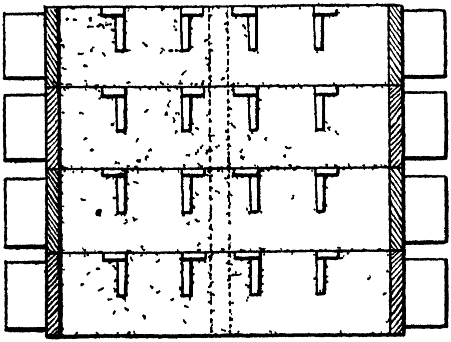


FIG. 31. DRAG PARTS ASSEMBLED FOR CASTING

In addition to the machines used in dressing ferrous castings, there are some machines almost peculiar to the non-ferrous fettling shop. Belt-driven gate and riser cutters are employed that will cut gates without fracture up to 1½ in. square at the rate of one per second. The cutter is set in operation by a foot lever, and immediately this lever is released the cutter stops at the top.

In some brass foundries circular saws are used for removing gates, but more often, perhaps, band saws are employed. In principle, these saws do not differ from those used for wood sawing, although the teeth are set and sharpened differently.

Reference has been made to the sand-blast tumbling barrels. A popular type of sand-blast apparatus is the rotary type. Sand blasting is quicker than pickling, gives as good a finish, and is cleaner and less expensive. With the thorough removal of the foundry sand, work in the machine shop is reduced, and wear on the tools is lessened. The rotary table machine above referred to is very suitable for work of a flat character. A slowly rotating table carries the casting and, after treating one side, the castings are turned over to expose the other side to the action of the blast, a curtain across the table admits the passage of castings under the nozzle, and at the same time prevents escape of sand or dust to the outside of the machine.

As sand blasting has become of great importance to-day, it may be explained that there are two systems of operation, the suction and pressure systems. The principle of the suction system is that of the ordinary injector, in which air, steam or water moving at high velocity induces forward another body. In sand blasting, a small mixer takes the place of the injector, this mixer being connected to the air pressure supply and to the supply of abrasive, usually by rubber hose or steel tubing, or, as in some machines, the abrasive may fall by gravity into the mixer. In the mixer the air and abrasive are mixed, and the abrasive discharged in the stream of air through the nozzle. In some machines the mixer with nozzle is fixed, in other machines the mixer with nozzle rotates, and in cleaning rooms the mixer with nozzle is portable. The suction system is very suitable for brass and grey iron castings, where the scale and sand do not adhere very closely. There is less wear and tear with the suction system than with the pressure system.

In the pressure system the method of producing a high velocity of discharge of the abrasive from the nozzle is entirely different from the suction system. There is a pressure unit with two compartments, the upper compartment being the storage chamber, the lower compartment the pressure chamber. Abrasive falls into the upper chamber and accumulates, whilst from the lower chamber abrasive, which has been previously fed from the storage chamber, is being forced under air pressure through the bottom regulating valve into the abrasive pipe, at which point it is met by a further supply of air under pressure, and is consequently forced along the abrasive pipe and discharged from the nozzle. The amount of abrasive passing through the valve into the abrasive pipe can be controlled and regulated, although it is not found necessary to adjust the valve when once it is set for any given condition of blasting requirements.

In addition to the rotating barrel and the table type sand blast, cabinets are used for medium size castings, while for general castings of a miscellaneous character there are sand-blast cleaning rooms.

Although the name "sand-blast" still persists, the actual abrasive now more generally used is not sand but chilled angular shot; which causes less harmful dust and is more effective. In the latest machines for cleaning castings this shot is discharged by centrifugal action from rapidly-revolving impellers, and not by jets of compressed air; the latter method being too extravagant in power consumption.

INDEX TO VOLUME II.

INDEX

The items in this index are grouped together in sections.
The numbers refer to pages.

SECTION V

PATTERN-MAKING

ALLOWANCES, pattern, 16
Aluminium patterns, 13

BAND saw, 100
Barrel construction, 36
Boxed-up construction, 34, 39
Brass patterns, 13

CAMBER, 18
Circular saw, 100
Composite patterns, 66
Contraction allowances, 17
Core-boxes, 69
Core-prints, 20
Cycloidal curves, 88
Cylindrical shell patterns, 32

FACE plates, 99
Fillets, 16
Forms of construction, 32

GAUGE sticks, 65
Gear tooth design, 87
Gearing, 86
Glue, 8

HALF-HEIGHT sweeping boards, 78
Hermaphrodites, 43

INVOLUTE curve, 88
Iron patterns, 9

JOINT plates, 49
Jointing patterns, 25
—— timber, 7

LOAM patterns, 62
Loose pattern sections, 29

MACHINING allowances, 19
Making gear teeth, 94
Metal patterns, 8
—— plates, 82

NAILS, 16, 33

ODONTOGRAPH, 91

PATTERN allowances, 16
—— for large cover, 56
—— for mixing pan, 55
—— plates, 80
—— shop machines, 95
Patterns for repetition work, 11
—— similar to castings, 41
Plaster of Paris, 14
—— —— —— plates, 83
Plywood, 5

REVERSIBLE plate, 81, 85
Rules for gearing, 87

SANDPAPER, 15
Sandpapering machines, 103
Screws, 16, 33
Segments, 33
Shell patterns, 42
Skeleton patterns, 38, 52
Small patterns, 32
Solid or block patterns, 44
Stop valve pattern construction, 49
Staves, 36
Strickle, 76
Stucco, 14
Sweeping boards, 59

TAIL-PRINTS, 24

Taper allowance, 20
Templets, 42, 53, 70
Timber, 5
——, seasoned, 6
——, warping, 6
Trimmers, 105
Turnover plate, 81, 83

VARNISH, 15

WAX plates, 82
Wood grinders, 104
—— millers, 105
—— plates, 82
—— turning lathes, 97

SECTION VI

IRON AND STEEL FOUNDING

ALLOY cast irons, 127
—— steels, 131
Annealing steel castings, 180
Artificially bonded sands, 134, 166
Assembling and closing moulds, 180

BALANCED-BLAST cupola, 116
Bedding-in method, 139, 148
Building loam patterns, 156–159

CLOSED moulds, 137
Coal dust, 136
Compo, 133
Contraction difficulties, 178
Converter, 118–120
Core assembly, 170
—— -blowing machines, 194
—— -drying plates, 169
—— -making machines, 183-191
—— —— materials, 165
Cores and core-making, 160
Crucible furnaces, 118
Cupola charges, 125
Cupolas, 112

DRESSING castings, 198
Dry-sand cores, 167
—— mixtures, 145
—— moulding, 144

EASING a casting, 179
Electric furnaces, 117
Electrically-operated moulding machines, 185

Fender heads, 177
Fluid pressure, 181

GAGGERS, 151
Green-sand cores, 167
—— mixtures, 136
—— moulding, 135
Grids, 152

HAND-MOULDING machines, 184

JOINTING moulds, 140
Jolt-ram moulding machines, 188

LOAM cores, 167
—— moulding, 152

MELTING equipment, 112
Metal for cylindrical retort, 156
Metal mixing, 124
Moulder's hand tools, 182
Moulding boxes, 138
—— machines, 183
—— materials, 132
—— sand, 132

NATURAL moulding sands, 133, 165

OPEN hearth furnace, 118, 122
—— sand moulds, 137

PICKLING castings, 199
Press moulding machines, 186

RAMMING, 139

Rotary core-making machine, 192
—— furnaces, 117
Runners and risers, 194

Sand blasting, 200
—— slinging machine, 190
Soldiers, 151
Spray runners, 177
Steel compositions, 129
Strainer cores, 175
Sweeping moulds, 153

Thicknessing, 154
Tumbling barrels, 199
Turnover method, 139
Tuyères, 115

Venting, 141

Wax vents, 170

SECTION VII

BRASS FOUNDING

Alloy mixtures, 215
Aluminium alloy castings, 251
—— founding, 236

Bentonite, 256
Brass, 216
—— and bronze moulding, 221
Bronze, 218

Chills, 222
Coke furnaces, 212
Core supports, 233
Cores, 242

Die casting, 246, 256
Dressing castings, 263
Dry-sand moulding, 227

Electric furnaces, 207
Elektron, 258

Fluxes, 257

Gas furnaces, 208
Green-sand moulding, 223

Heat-treatment of castings, 252, 258

Lift-out castings, 208, 214
Loam moulds, 234

Machine moulding, 260
Magnesium alloy founding, 255
Magnuminium, 257
Match plates, 261
Melting aluminium alloys, 248
—— equipment, 206
Moulding sand, 256
Multiple moulding, 262

Oil furnaces, 210

Plate moulding, 260
Pouring metals, 234
Pyrometers, 235

Ramming, 240
Reverberatory furnaces, 215
Runners, 228

Sand blasting, 265
—— casting, 238
Silica sand, 222

Tilting furnaces, 208, 214

Venting, 225

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